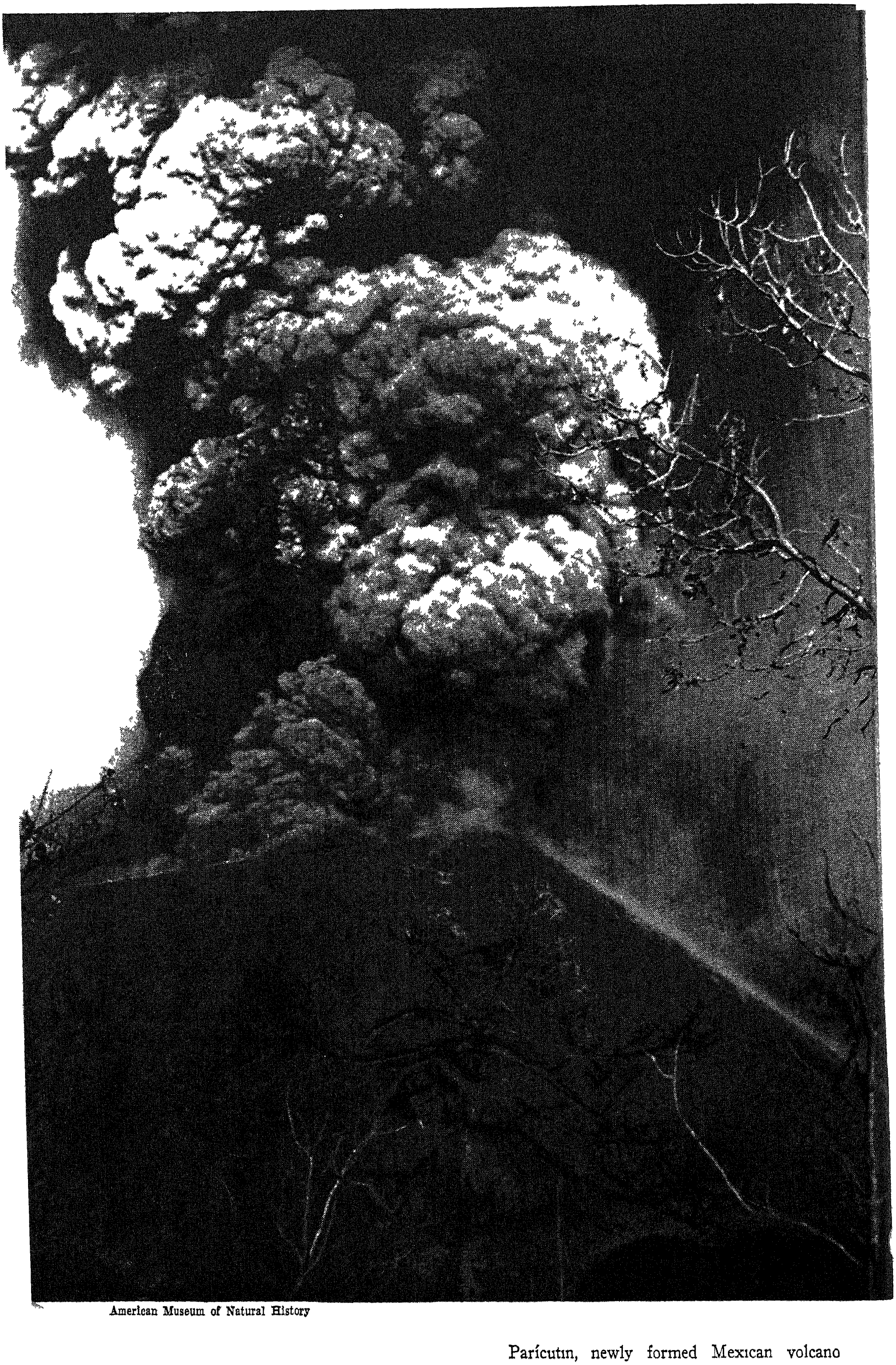
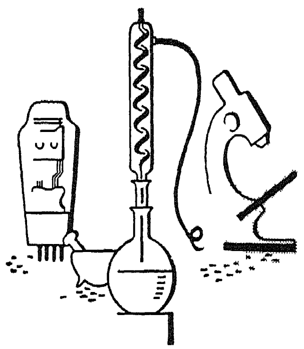


American Museum of Natural History

Parícutin, newly formed Mexican volcano

THE BOOK OF
POPULAR SCIENCE



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ROCKETS

Swift Travelers in Air and Space

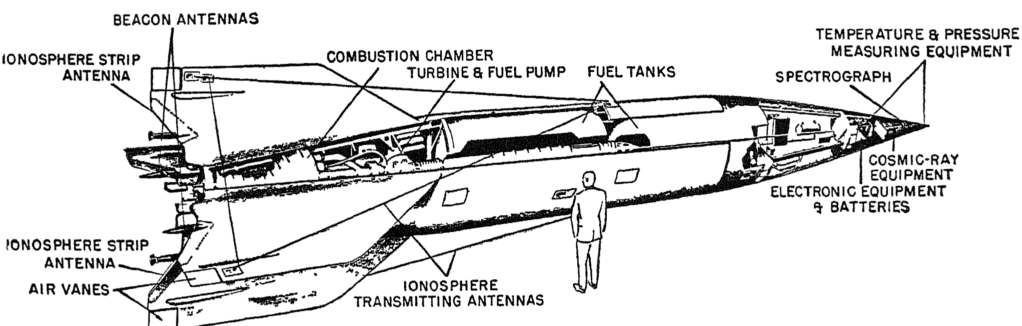
UP to a comparatively short time ago, most people thought of the rocket only as a spectacular kind of fireworks — first a fiery trail leading skyward, then a clap of thunder followed by a gorgeous burst of stars. Today the rocket has come into its own with a vengeance. It is one of the world's deadliest weapons; it has made flights in the upper atmosphere and, indeed, it is even being seriously considered for one of man's most cherished projects — interplanetary flight.

The principle of the rocket is simple enough. If we fill a toy balloon with hydrogen gas under high pressure, the gas will press equally upon every part of the balloon. If we prick it with a pin, the gas will begin to escape through the hole, and there will be less pressure in this area. The pressure at the opposite end will therefore be relatively greater and the balloon will move away in that direction. In the rocket, high-pressure gases are produced by the combustion of fuel. These gases make their way through an opening at the rear of the rocket and consequently give it a forward thrust.

The Chinese began to use rockets for fireworks displays several hundred years before the birth of Christ. This kind of rocket is still popular. It generally consists of a cardboard case, closed at one end and fastened to a stick. For the greater part of its length the rocket is filled with gunpowder; an open space is left in the middle. An explosive charge and a number of "stars" made of inflammable material are set in the head. The gunpowder charge is ignited and the rocket shoots upward. When the charge in the head explodes, the stars are ignited and fall in showers.

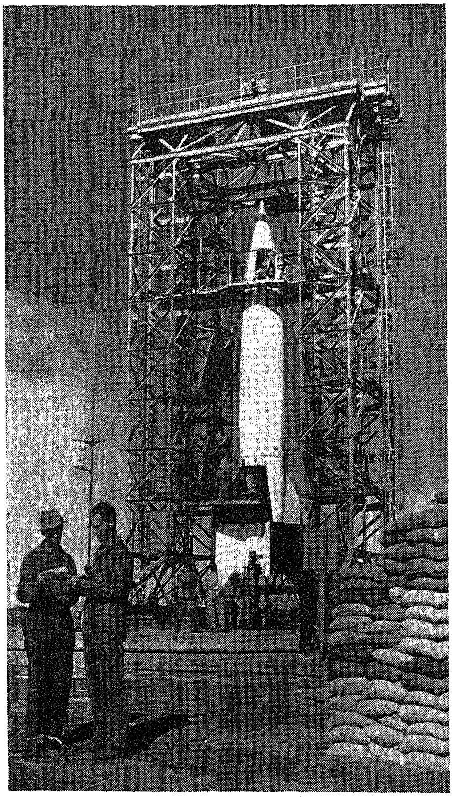
Rockets served as weapons at least as far back as the eighteenth century. Tippoo Sahib, who was sultan of Mysore in the last years of the eighteenth century, fired a number of rocket projectiles at his English foes. Greatly impressed by Tippoo's rockets, the English decided to adopt the weapon; and several English rocket ships took part in the attack on the American stronghold of Fort McHenry in September 1814. Francis Scott Key, who was an eyewitness of the battle, immortalized the "rockets' red glare" in a line of THE STAR SPANGLED BANNER.

The rocket of those days was very erratic in flight but it could compete with round shot, grape shot and chain shot because they too were hit-and-miss projec-



U S Navy

Diagram of a V-2 rocket that soared some 100 miles into the upper air over White Sands Proving Ground, Las Cruces, New Mexico. A number of scientific instruments were carried in the rocket's warhead (forward section), which would be loaded with high explosives if it were used against a foe.



Rockets launched in vertical flight are made to deviate a bit from a straight upward path, so that they will not crash too near the launching site.

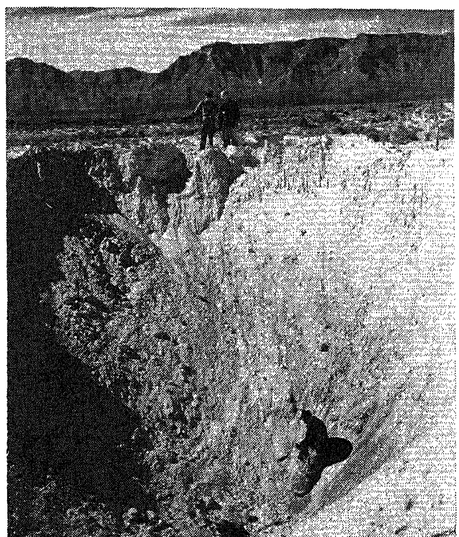
tiles. When the far more accurate rifled shell came into general use the rocket was abandoned as a military weapon, but continued to be used in other ways. It was still a favorite kind of fireworks; it was employed for signaling purposes; and it served to carry lines between wrecked ships and the shore.

In the course of World War II the rocket was restored to military favor. The Russians used a rocket-firing gun, the Katiusha, which launched a considerable number of projectiles at the same time. The United States developed the rocket-firing bazooka; with a comparatively small rocket, this weapon could knock out a good-sized tank. Rockets were also launched from ships and airplanes and added greatly to their firepower.

The most deadly of all rocket weapons was the gigantic German V-2, an aerial bomb with which the Germans showered London in the early months of 1945. The V-2 rockets were over 45 feet long and weighed 12 tons at the take-off. Fired from the Dutch coast, they reached an altitude of 65 miles and bridged a horizontal distance of 200 miles. The great damage they inflicted was all the more frightful because, traveling faster than sound, they gave no warning of their approach.

The rocket projectile is now a standard weapon for modern armies, navies and air forces. Its main parts are the warhead, containing the explosive charge; a fuse for exploding the warhead when it reaches the target and finally the motor. This contains the fuel, an igniter and a venturi or nozzle through which the exhaust gases pass. The projectiles are often provided with fins in order to assure stability in flight.

Military men are particularly interested in long-range rockets, for they are a devastating offensive weapon. They can pepper an enemy with high explosives from a distance of several hundred miles; and their range is being steadily increased.



Both photos, General Electric

Crater made by a crashing V-2 rocket at the White Sands Proving Ground. As there was no explosive in the rocket's warhead, the size of the crater shows with what force it struck the desert floor.

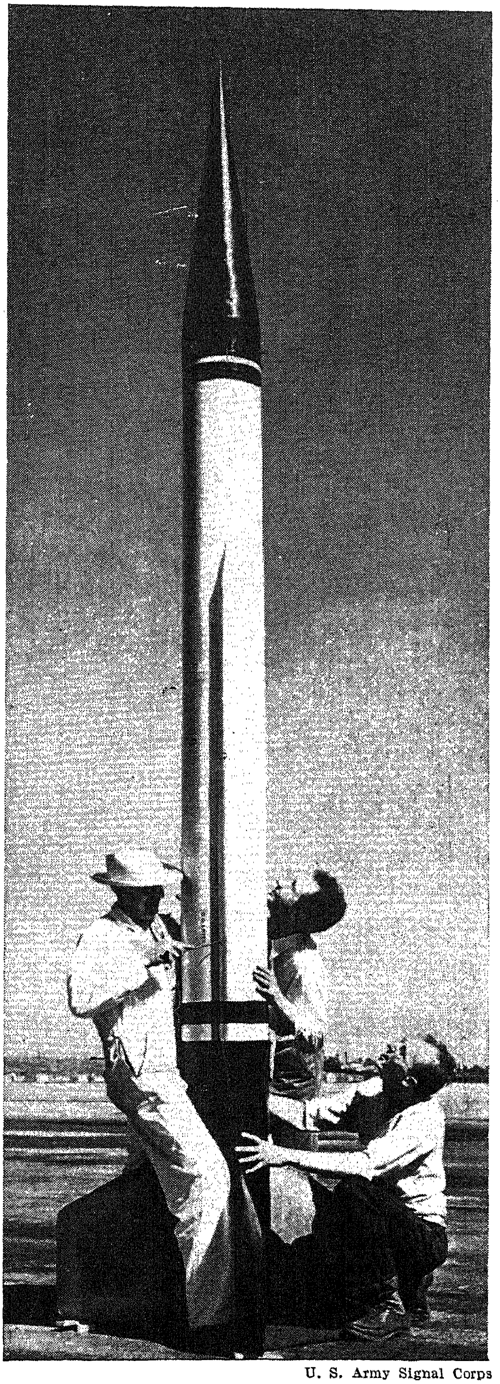
There is no adequate defense against these weapons, as Londoners found to their cost in the dark days of 1945; the only way to stop them is to destroy their launching sites.

The United States Army has been among the leaders in the field of long-range-rocket research. It has been experimenting with V-2 rockets, made on the general model of the German V-2; it has also given much attention to the American-made WAC-Corporal, which is only about eleven feet long.

On February 23, 1949, a historic flight took place over the White Sands Proving Ground in New Mexico; a rocket soared far up in and perhaps above the ocean of air that we call our atmosphere. This flight was really a two-stage affair with two rockets — a V-2 and a WAC-Corporal — taking part in it. The WAC-Corporal was set in place in the nose of the V-2. When the latter reached an altitude of about 20 miles and a velocity of a mile a second, the fuel in the WAC-Corporal was ignited. Shot upward from the bigger rocket, the WAC-Corporal reached the height of 250 miles before its fuel was exhausted and the force of gravity sent it crashing down to earth.

Long-range rockets are not only extraordinarily effective military weapons; they have great peacetime possibilities, too. As a matter of fact, they have already added greatly to our knowledge of the upper air.

They have provided a means for recording the temperature at different levels of the atmosphere. For this purpose experimenters have utilized a thin wire of wolfram (tungsten) or platinum set in place just outside the casing of the rocket; this is connected with a low-voltage battery in the rocket. The amount of current flowing through the wire at any given time will depend on the temperature of the outer air. An automatic radio in the rocket sends a record of current variations to a recorder on the ground. By interpreting this record, an observer can verify the temperature readings at the different atmospheric levels with a high degree of accuracy.



U. S. Army Signal Corps

Working on a WAC-Corporal, a high-altitude rocket developed by the United States Department of Ordnance. The WAC-Corporal is only about eleven feet long and is much smaller than the V-2.

High-flying rockets have also supplied new information about the light of the sun. A spectrograph, an automatic camera that photographs the spectrum of the sun, is mounted in the nose of the rocket; it is controlled in such a way that it takes pictures at regular intervals. In the course of its flights on the V-2, the spectrograph has shown, among other things, that the ultraviolet light found at sea level does not become much stronger until a height of 20 miles is reached. Between 20 and 40 miles its intensity increases greatly. We know why. This twenty-mile layer in the atmosphere contains a good deal of ozone, a form of oxygen that gobbles up ultraviolet light. This is a good thing for us. If too many ultraviolet rays filtered through to us, we would literally be sunburned to death. As it is, enough ultraviolet light comes through to earth to create in us and in living plants vitamin D, which is necessary for health.

There is little atmospheric pressure at a height of 70 miles

At sea level, atmospheric pressure is 14.7 pounds per square inch. V-2 flights have shown that at a height of 70 miles the pressure is only .000002 of a pound. This means that there is almost no air at all at this height, since atmospheric pressure is caused by the air as it is pulled down by the force of gravity. In fact, at the 70-mile mark, there is more of a vacuum than we could obtain for the average laboratory experiment.

We know more about cosmic rays now than we did before rockets rose into the upper air. These rays, which consist of electric particles from outer space traveling at great speed, are absorbed in great part by the atmosphere through which they pass before they hit the earth. V-2 flights have shown that at a height of 15 miles above sea level, the intensity of cosmic rays has increased about a hundred times. At greater distances the intensity falls off.

Will men ever travel to the moon or to Mars or other planets? If they do, it will probably be in rockets, for the rocket is the only source of power so far developed that could be used for this purpose.

To understand why this is so, let us recall that the air thins out rapidly above the earth, and that long before we pass beyond our atmosphere, we are in what is really a vacuum. Propelled craft could never fly here, since they must screw their way through the air if they are to remain aloft. As for jet-propelled craft, their fuel can burn only when it is mixed with oxygen from the outer air; hence a jet plane would never be able to fly in space.

A long-range rocket-propelled plane, however, would be entirely independent of the oxygen contained in the atmosphere, since it would carry within itself the oxygen required for combustion. In the V-2, for example, the grain alcohol that is used as a fuel is mixed with liquid oxygen, contained in a separate tank; in the WAC-Corporal the fuel, aniline, is mixed with nitric acid, which has 48 parts of oxygen to 14 parts of nitrogen and one part of hydrogen.

Thus far, it is true, the rocket's role in passenger flight has been very modest. Jato units, consisting of one or more rockets attached to a jet plane or propellered plane, provide extra power for take-offs; these rocket units are generally discarded once the plane is in flight. (Jato comes from the capitalized letters in the word Jet-Assisted Take-Off.) Rockets have been used, too, to provide sudden spurts of power while planes are in the air. But aircraft propelled entirely by rocket engines are still in the experimental stage.

Rocket space ships may be a reality before the end of this century

The long-range rocket must be greatly improved before it can serve as a reliable and safe passenger plane. Many problems must be solved, too, before men can venture on a rocket-powered flight to our nearest celestial neighbor, the moon. But such a flight is not as fantastic as it might seem to be. Already reputable men of science have predicted that it will take place some time in the present century. Perhaps you who are now reading these lines will be among the first to step upon the barren crags of our satellite!

GLASS HOUSES

New Uses for an Old Material

GLASS HAS CONTRIBUTED an important share to the development of the civilization which we enjoy. With the advent of hollow glass blocks, glass now promises to play an even greater part than hitherto in providing us with comfortable, healthful, convenient shelter at home, at work, and at play.

Like glass itself, the beginnings of which are unknown though records indicate that the Egyptians practised glass-blowing some four thousand years ago, the launching of glass block took place at an undetermined date. Some glass technicians believe that glass blocks were first made in Holland about twenty-five years ago, while others declare that various European glass companies experimented with glass in block form long before that. Its present successfulness, however, must be credited to the improvements which have been made in the manufacture of glass blocks and to the desirable characteristics which these innovations have added. This past decade witnessed the rapid development in technique which made possible a practical glass block capable of being manufactured economically at a high production rate, and for a price which would permit its general use in construction.

Popularity and acceptance have been quickly won by this new and versatile masonry material. Glass block construction offers new possibilities wherever it is desired to obscure the view without sacrifice of light, wherever additional light is required, or wherever natural or artificial light must be considered for utility or decoration. Though recently introduced, glass block is already widely used in homes and offices, in schools and hospitals, in packing plants and factories, in hotels and theatres.

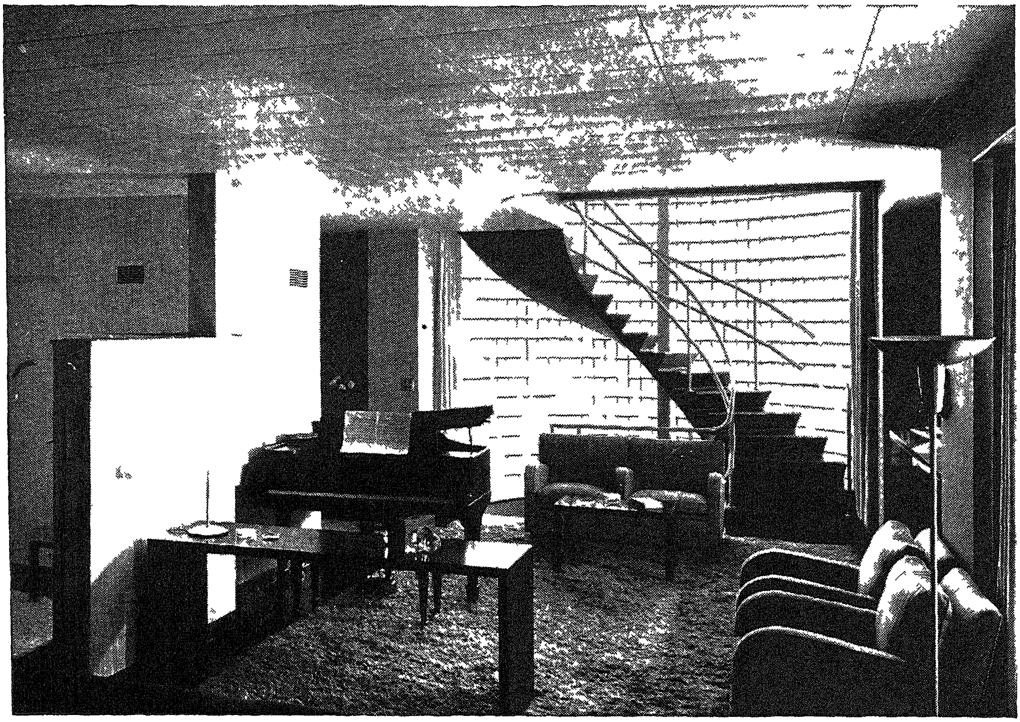
Glass blocks, such as the Owen-Illinois Glass Company's "Insulux," and the Pittsburgh Corning Corporation's "PC," are hollow, partially evacuated, clear units of pressed glass. These blocks are made available in standard sizes and face patterns. The various patterns have been evolved through intensive research to obtain not only varying degrees of light but also a selection of decorative effects. The face patterns are designed to reduce glare resulting from spotty concentration of light.

The intensity of the light transmitted is controlled by the face pattern selected. The amount of incident light transmitted by various Insulux patterns ranges from 86.5 per cent to 11.7 per cent. The average transmission of light through each of the two standard PC designs is 78 per cent. Thus interior lighting may be controlled within a wide range of practical limits. The transmitted light is diffused and is comparable to the light from a northerly exposed window or skylight. Such reduction of glare and shadows in lighting promotes comfort, efficiency and quality workmanship, and is particularly desirable for close work. The amount and character of the diffusion is, of course, dependent on the design of the prismatic pattern of the glass block selected.

Glass blocks are not offered as a load-bearing material yet they possess ample compressive strength to be self-supporting within the limits prescribed by the ratio of their thickness to any practical height. The ultimate strength developed by individual Insulux glass block units is 800 pounds to the square inch. The ultimate strength of panels of such glass block, laid up in accordance with certain specifications, is 400 pounds per square

inch. Common practice in design of Insulux wall panels assumes a safe load value of 100 pounds per square inch.

These panels have successfully withstood with no visual failure, air pressures up to 120 pounds per square foot. Pressures on the panels corresponding to a wind velocity of more than 160 miles per hour indicated deflections of but 0.08



Courtesy Owens-Illinois Glass Co

THIS GLASS BLOCK STAIR WALL IN A PRIVATE RESIDENCE ADMITS LIGHT WITHOUT SACRIFICING PRIVACY

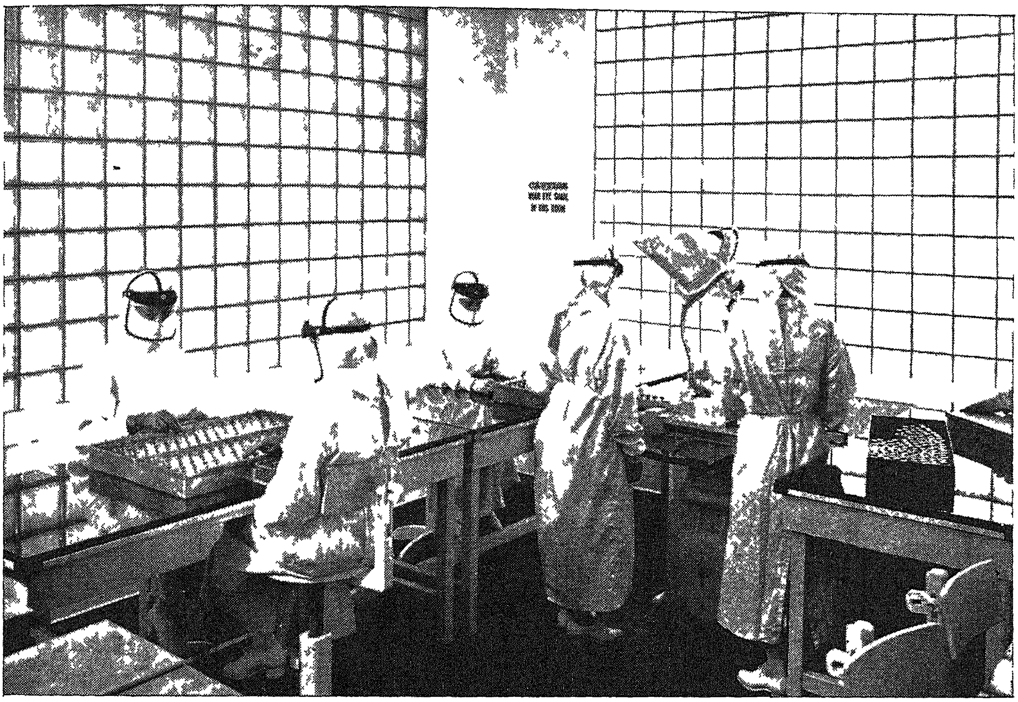
inches. Such results show that these glass block panels will withstand, with a more than adequate factor of safety, the usual building code wind pressure allowance.

In the manufacturing process the air in the hollow glass block is trapped at a very high temperature. When the block is cooled, it contains only thoroughly dry air at a partial vacuum. This rarefied dead air trapped in a small volume forms an excellent heat insulator. A glass block wall only 3⅞ inches thick, the width of a block, is equivalent in insulation value to a 12-inch plastered brick wall and a 20-inch unplastered concrete wall.

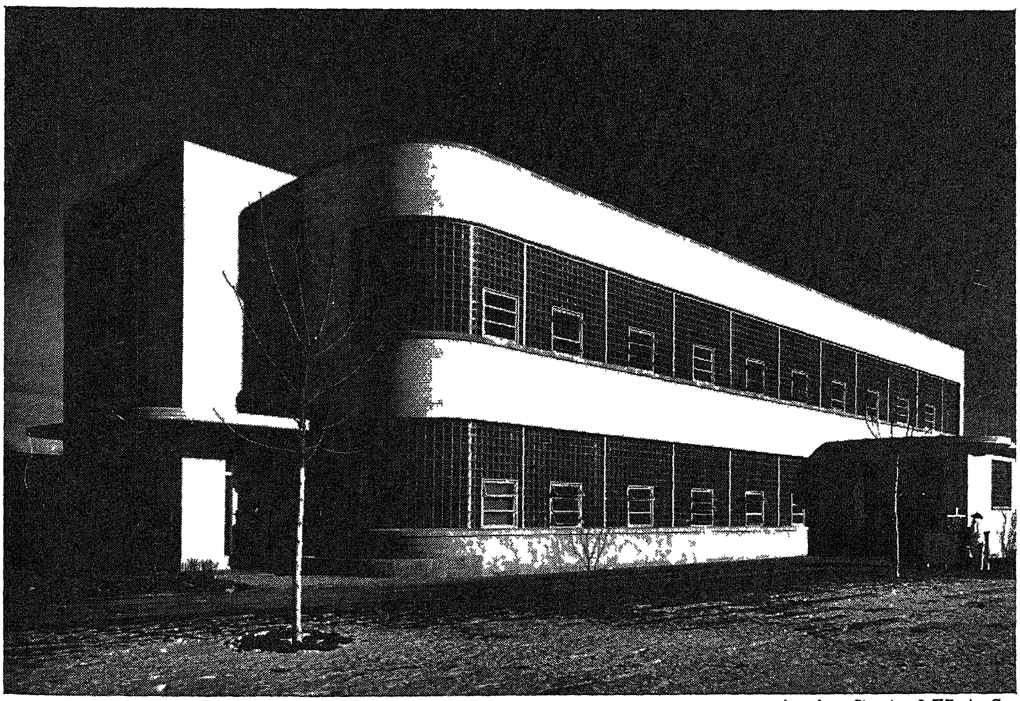
Condensation forming on the inside of windows during cold weather causes deterioration of sash and adjacent materials. It is particularly prevalent in buildings, such as tobacco factories, silk mills, paper mills and dairies, where a high humidity is maintained. Partially evacuated glass blocks, because of their high insulating value, will, under most conditions, eliminate this condensation and the resulting deterioration. At the conclusion of extensive tests of Insulux, Purdue University reported that the outside temperature necessary to produce condensation on the inside surface, when the inside air is 70° and the relative humidity is 40 per cent, was —16 4° for glass block and 36° for steel sash.

Glass blocks, because of their variable values of controlled light transmission, due to the variety of available face patterns, can be employed to reduce materially the transmission of solar heat. Purdue University laboratory author-

THE USEFULNESS AND BEAUTY OF GLASS BLOCKS



Glass blocks provide good light for this chemical laboratory, where penicillin is being put in vials.



American Structural Effects Co.

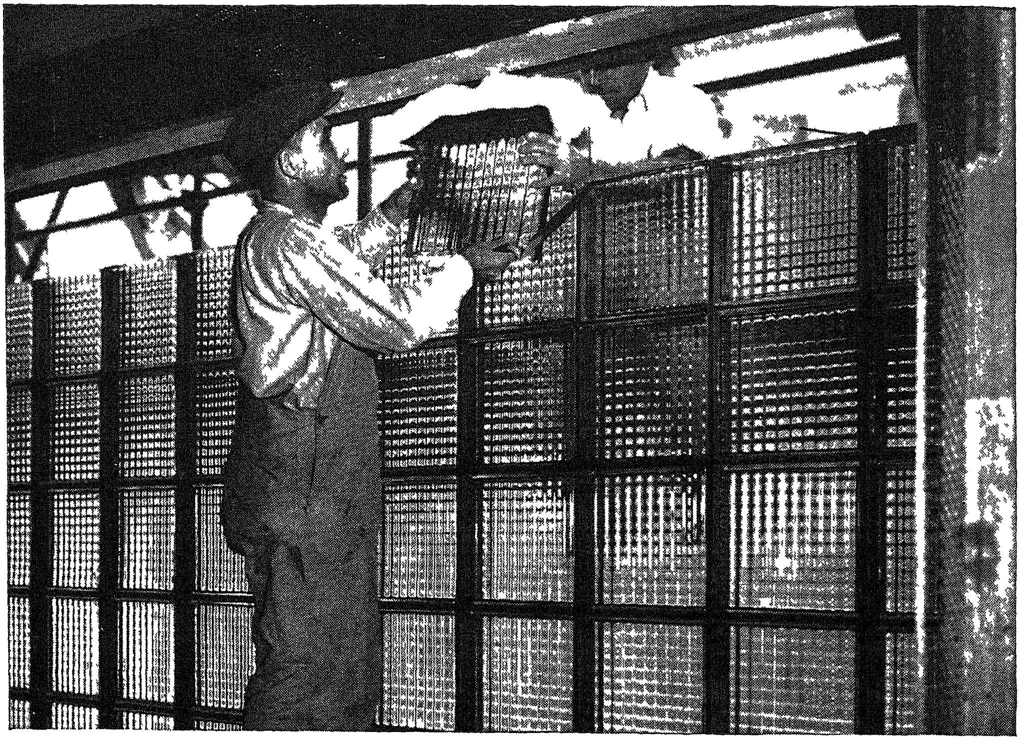
Glass blocks produce a pleasing architectural effect, as this photograph of a modern dairy shows.

ities, testing equal areas of steel sash and Insulux blocks under varying conditions, concluded that the latter material permitted from 38 per cent to 51 per cent less heat to pass.

Tests to determine sound transmission through glass block panels were conducted in the Sound Chamber of the National Bureau of Standards, Washington, D. C. The transmission loss was shown to compare favorably with the usual type of plastered partition used in fireproof construction.

Glass block walls are easy to clean. It is the natural characteristic of glass to be non-absorbent to liquids and odors. Several of the glass block panels have smooth exterior faces, the prismatic patterns being impressed only on the interior faces of the block. In other designs the faces have simple ribs running vertically on the exposed exterior and horizontally on the interior. The character of these surfaces minimizes the accumulation of surface dirt.

Glass block walls and panels require no maintenance other than occasional cleaning. The hard, brilliant surface of the block does not disintegrate or craze. It is not affected by weather and cannot be easily written upon, marked or defaced. Obviously, glass blocks do not oxidize nor require painting.



Courtesy Corning Glass Works

BRICKLAYERS ERECTING A GLASS BLOCK WALL THE WHITE WOOLY SUBSTANCE ON TOP OF THE BLOCK BEING INSERTED IS FIBROUS GLASS FOR INSULATION

A damaged glass block can be removed easily from the wall by chipping out or by drilling holes in the mortar joints in opposite corners and then inserting a keyhole saw through the joint and sawing out the block. The new block is then buttered with mortar, inserted in place and the job completed by pointing.

Building projects making use of glass blocks in every type of structure have been completed and others are under way or planned throughout the United States and Canada.

THE STARS IN THEIR COURSES

The Naming of the Constellations and the Making of the Map of the Sky

WHY STARS TWINKLE AND PLANETS DO NOT

WE now enter upon a vaster study. The sun and its system of planets, which have seemed to be proportioned upon such a prodigious scale, must dwindle in our imagination until they become a mere point of light in the black heavens, one star among uncounted millions. Gazing at the starry skies upon a moonless night, and letting our vision wander through their brilliant labyrinth, let us realize that somewhere in that innumerable company floats a star which is our sun. Our earth and solar system are henceforward only our standpoint and observatory.

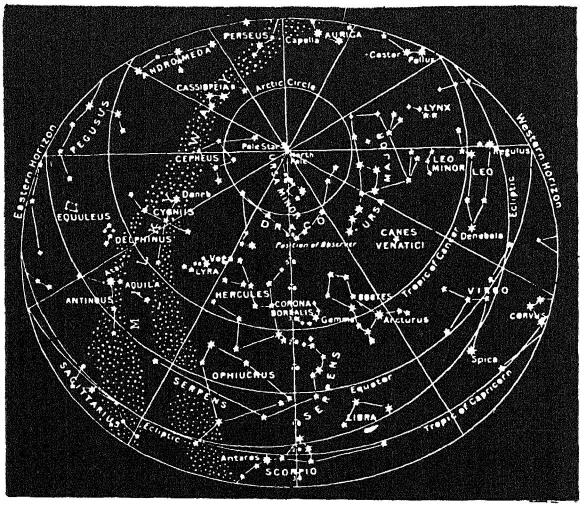
Viewed from this drifting point in infinite space, the heavenly bodies appear to be projected upon the inside of a hollow sphere; and so projected, they fall into various patterns or figures, of which the more conspicuous have been known from ancient times as "constellations". These figures are quite arbitrary; for the most part, though not always, revealing no astronomical relationship between the stars which enter into each of them. They do not necessarily show actual nearness of the stars which form them; for the stars are seen in perspective, so that of two which appear quite close together upon the hollow sphere, one may be immeasurably away behind the other.

Again, the stars might have been grouped in quite other figures than those that have been handed down to us by tradition. Indeed, the present arrangement is, in many cases, not the most convenient which might have been made. Sir John Herschel said of it that "the constellations seem to have been almost purposely named and delineated to cause as much confusion and inconvenience as possible Innumerable snakes twine through long and contorted areas of the heavens where no memory can follow them; bears, lions, and fishes, large and small, northern and southern, confuse all nomenclature."

This, however, is the language of exaggeration. Only eighty-eight constellations are recognized by modern astronomy, and divide among them the whole area of the celestial sphere; and the confusion which is caused by their irregularity is as nothing to that which would arise if astronomers were free to invent at will new combinations of stars. Moreover, the very antiquity of the constellations, of which many were fixed by early Chaldean star-gazers, deserves our respect. The names of Orion, the Pleiades and others, are as old as literature.

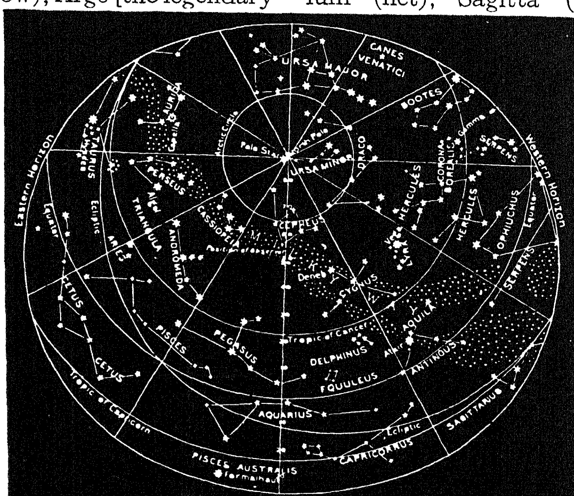
A Greek astronomer, Eudoxus of Cnidus, wrote a treatise upon the stars, dividing the heavens into the constellations as these were known in the fourth century B.C. He enumerated forty-five groups of stars, but the number was increased to forty-eight by Ptolemy of Alexandria, in the second century A.D. From this time the system of constellations remained fixed until it was revised by Johann Bayer, who published in 1603 a chart of the heavens which, for that age, was wonderfully complete. Besides adding twelve new constellations to those already accepted, Bayer devised the method by which the stars in each constellation are individually distinguished by letters of the Greek alphabet in accordance with their brilliancy, the most brilliant being described as α, the next as β and so on.

A considerable number of other constellations were added by Tycho Brahe and succeeding astronomers until the middle of the eighteenth century, when the process was fortunately brought to an end. But the precise boundary lines of the constellations remained undetermined until this work was undertaken in 1840 by a committee of the British Association. The whole hollow sphere of the sky was by this committee definitely divided by unmistakable boundaries into the irregular areas of the various constellations.



THE CONSTELLATIONS VISIBLE IN SPRING
As seen at midnight about the middle of May.

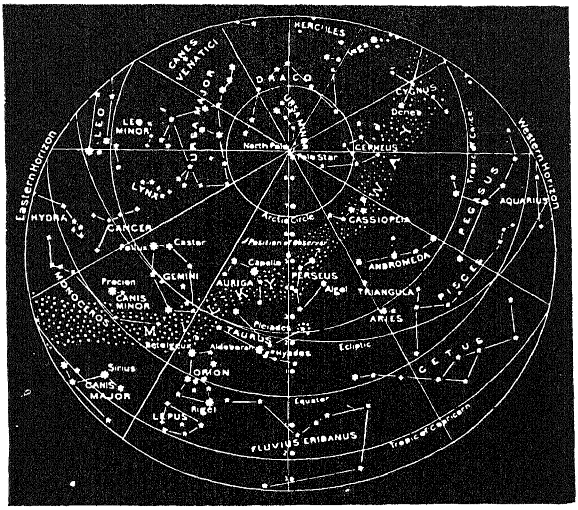
These constellations, or "asterisms" as they are also called, are as follows. Andromeda, Antlia (air-pump), Apus (bird of paradise), Aquarius (water-carrier), Aquila (eagle), Ara (plow), Argo [the legendary ship, subdivided into Carina (keel), Puppis (poop), Vela (sails) and Malus (mast)], Aries (ram), Auriga (charioteer), Boötes or Arctophylax (the bear-keeper), Camelopardalis (giraffe), Cancer (crab), Canes Venatici (hunting dogs), Canis Major (greater dog), Canis Minor (lesser dog), Capricornus (goat), Cassiopeia, Centaurus (the centaur), Cepheus, Cetus (whale), Chameleon, Circinus (compasses), Cœlum (heaven), Columba (dove), Coma Berenices (hair of Berenice), Corona Australis (southern crown), Corona Borealis (northern crown), Corvus (crow), Crater, Crux (cross), Cygnus (swan), Delphinus (dolphin), Dorado (goldfish), Draco (dragon), Equuleus (foal), Eridanus (name of an ancient river), Fornax (kiln), Gemini (twins), Grus (crane), Hercules, Horologium (clock), Hydra, Hydrus (water serpent), Indus (Indian), Lacerta (lizard), Leo (lion), Leo Minor, Lepus (hare), Libra (scales), Lupus (wolf), Lynx, Lyra (lyre), Mensa (table), Microscopium (microscope), Monoceros (unicorn), Musca (fly), Norma (rule or square), Octans, Ophiuchus, Orion, Pavo (peacock), Pegasus, Perseus, Phœnix, Pictor (painter), Pisces (fishes), Piscis Australis (southern fish), Piscis Volans (flying fish), Reticulum (net), Sagitta (arrow), Sagittarius (archer), Scorpio (scorpion), Sculptor, Scutum Sobieski (shield of Sobieski), Serpens (serpent), Sextans (sextant), Tauras (bull), Telescopium (telescope), Toucan, Triangulum (triangle), Triangulum Australe (southern triangle), Ursa Major (greater bear) — also called as well the Plow, Charles's Wain, or the Dipper, Ursa Minor (lesser bear) — also called the Little Dipper, Virgo (virgin), Vulpecula (little fox).



THE CONSTELLATIONS VISIBLE IN SUMMER
As seen at midnight about the middle of August.

It is a queer list of names, mostly "a menagerie stocked from the banks of the Euphrates", with a few names of mythical

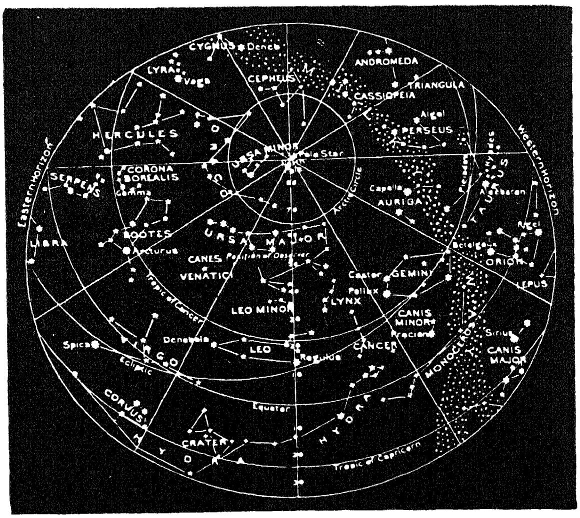
heroes, and a few objects of human handiwork. Strangely enough, there is not one constellation named from the vegetable kingdom, not an oak nor lily nor rose, as if these ancient Chaldeans had eyes only for beasts. Giordano Bruno suggested naming the constellations all over again, with the names of the virtues; and Julius Schiller, not long afterwards, would have changed them into monuments to the saints, but they are better left as they are. No modern could have named them so exuberantly; our eyes see only geometrical figures.



THE CONSTELLATIONS VISIBLE IN AUTUMN

As seen at midnight about the middle of September

Not only constellations, but individual stars also, have names; some grand, as Sirius and Arcturus; some uncouth, yet magnificent too, as Betelgeux, Aldebaran and Fomalhaut. These last are Arabic, memories of the time when the Arabs were the first mathematicians and astronomers of the world. But such kingly names as these are not for modern science; we now designate them by their serial number in some catalogue or according to some other equally practical but wholly unimaginative scheme.



THE CONSTELLATIONS VISIBLE IN WINTER

As seen at midnight about the middle of February.

The number of fixed stars which are visible under the most favorable conditions, without telescopic aid, in the entire sky of the north and south hemispheres, is about nine thousand. From any one position on the earth, and at any one time, not more than four thousand can be seen, even in the sky of a perfectly dark, clear and moonless night, because many, visible were they overhead, are hidden by the deep atmosphere towards the horizon. The atmosphere cuts off the light of a vast number of stars; if it were removed we should see eight or ten times as many. With an ordinary field-glass a vastly greater number of stars can be seen than are visible to the naked eye. The smaller stars are far more numerous than the larger; so in general the total light given by stars of the second magnitude is more than that given by those of the first, and from stars of the third class more than from those of the second, and so on throughout the first eight or ten magnitudes. The stars which are invisible to our eyes shed more than three times as much light upon a starlit scene as those which can be separately perceived, and the total amount of starlight, according to careful measurements made by Yutema and Rhijn, is equal to one-200th of the light of the full moon. It is impossible to give more than a very rough estimate of the total number of stars which are visible by means of the

most powerful telescopes. In the examination of the figures that follow, we must bear in mind that even among authorities wide differences exist with regard to the number of stars that can be seen. Several good authorities accept sixty millions as a probable figure for the number of stars made visible by the telescopes with apertures of 36 and 40 inches. It is estimated that the 200-inch telescope would, with optimum conditions prevailing, make some one billion stars visible, a figure which is double that for the 100-inch telescope at Mt. Wilson. We realize that it is utterly impossible to estimate the number of stars in the universe, when we remember that there are hundreds of millions of spiral galaxies, each containing probably many billions of stars like the sun.

Magnitude in astronomy a term not indicating size but brilliancy of a star

A star's apparent magnitude is a term indicating its brilliance as noted from the earth, and does not indicate what the actual size of the star may be. The apparent brilliancy of a star depends on three factors — its actual size, its actual brilliancy, and its distance from the observer. In the vast majority of cases not one of these factors is known. A star which is actually large and brilliant in comparison with others may yet appear less brilliant than they, if it is much further away from us than they are.

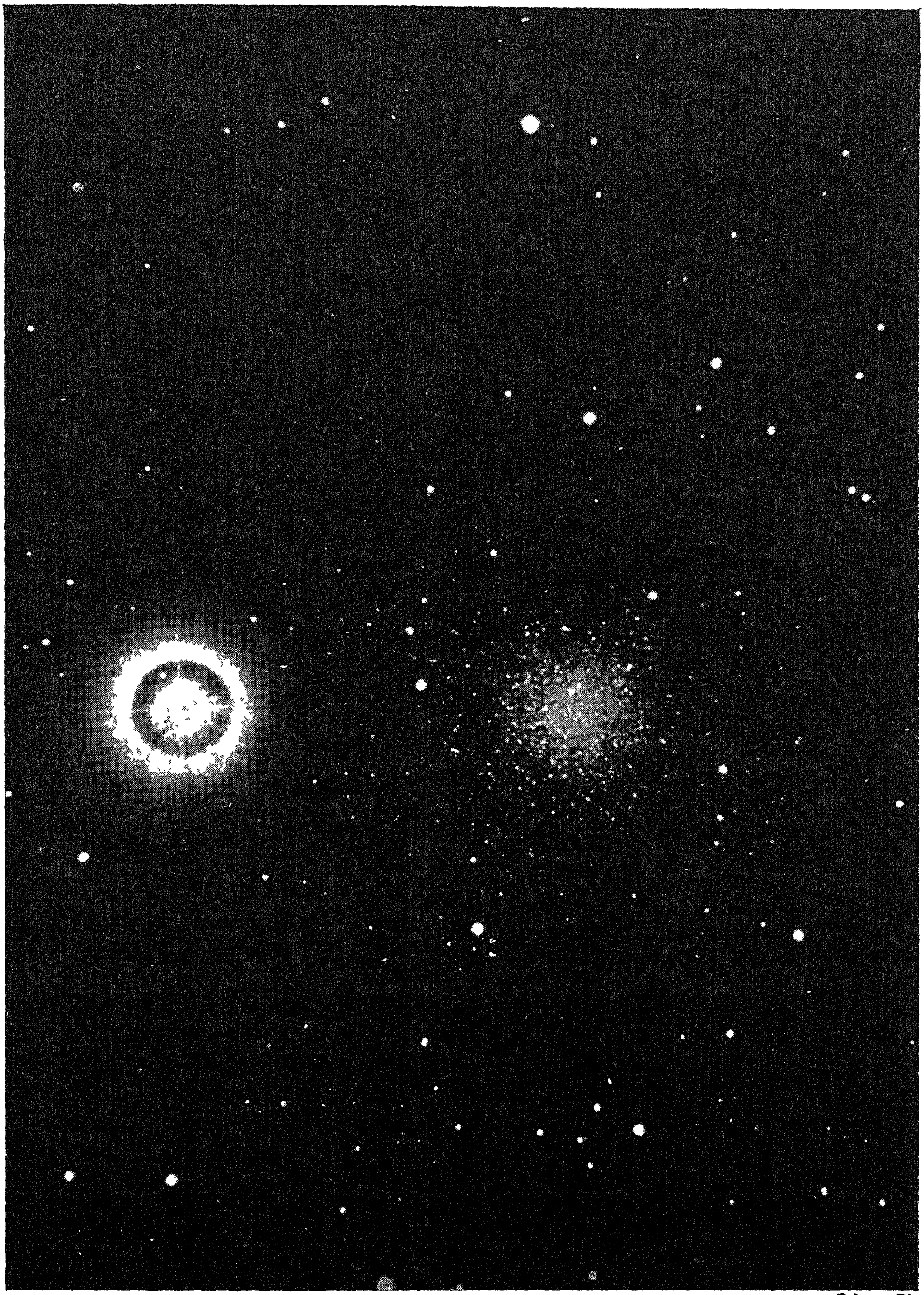
The stars which are visible to the unaided eye were divided by ancient Greek astronomers into six classes; and their method of classification, made more precise and extended to include the less brilliant stars which are visible only by means of the telescope, is in universal use today. The brightest stars are those of the first magnitude, of which there are ten in the northern and ten in the southern hemisphere of the heavens; those which are just visible without the aid of instruments are of the sixth magnitude; and the stars which are intermediate between these two classes are graded as being of the second, third, fourth and fifth magnitudes. The stars of the first and of every succeeding class differ of course greatly in brightness among themselves, because this classification is quite arbitrary, so that a star which is just within the first class may be but little brighter than a second magnitude star which is among the most brilliant of its class. Yet an average brightness for each class may be estimated; and when this is done, it is found that an average first magnitude star is about one hundred times as bright as an average star of the sixth magnitude. This implies that each magnitude is very nearly two and a half times as bright as the next succeeding magnitude, and the same proportion holds all through the scale. A star of the first magnitude is one hundred million times as bright as a star of the twenty-first magnitude.

The minute classification of stars by their brightness

In view of the fact that the stars of any one class differ among themselves to such an extent that one of them may be more than twice as bright as another, the classification is now made more exact by admitting decimal figures. Thus, besides the magnitude 2, we may specify stars as being of the magnitudes 2.1, 2.2, etc., in a descending scale of brightness, down to the magnitude 3. And further, in view of the fact that the twenty stars included in the first class differ among themselves to a degree much exceeding the limits of a magnitude in other parts of the scale, it has been found necessary to establish a magnitude zero to indicate two and a half times the brightness of the normal first magnitude; and above zero, again, the magnitudes of minus one, and even minus two, have been used to express the brightness of Sirius and of the planet Jupiter respectively.

Among the stars of the first magnitude are Achernar (in the constellation Eridanus), Aldebaran (Taurus), Altair (Aquila), Antares (Scorpio), Arcturus (Boötes), Betelgeux (Orion), Canopus (Argo), Capella (Auriga), Alpha Centauri (Centaurus), Deneb (Cygnus), Fomalhaut (Piscis Australis), Pollux (Gemini), Procyon (Canis Minor), Regulus (Leo), Rigel (Orion), Sirius (Canis Major), Spica (Virgo), Vega (Lyra).

THE 200-INCH TELESCOPE AT WORK



Palomar Pix

The 200-inch Palomar Mountain telescope reveals NGC 2419, a group of stars on the fringe of the Milky Way and about 185,000 light-years from the earth. (A light-year is about 6 trillion miles.)

The use of photography in the measurement of brilliancy

The degree of brilliancy which is possessed by any star may be estimated by comparing it with other stars without the aid of instruments for measuring light, and an experienced observer can in this way arrive at wonderfully accurate results. In general, however, a photometric instrument of some kind is used. Photography affords a fairly trustworthy method of comparing the brilliancy of stars which appear upon the same plate, except when the stars differ in color and therefore in photographic activity; hence there are two scales of magnitudes used, the photographic and the photovisual. Those commonly employed are the visual.

Although the stars are in effect only points of light and not surfaces, yet a brighter point of light comes out in a photograph as a larger spot of light than the spot which is made by a less brilliant point of light. More exact measurements of brilliancy may be made by sliding a tinted glass of gradually increasing thickness across the eyepiece of the telescope, and noting the precise point at which the image of the star disappears altogether; and other more complicated photometers using a selenium cell or a photo-electric cell are now widely employed for the determination of star magnitudes when the highest possible precision is necessary.

Why stars twinkle most vividly nearest to the horizon

A rough and ready way of distinguishing fixed stars from planets is afforded by the fact that the former scintillate or twinkle and the latter do not do so. Not indeed that the twinkling has its origin in the fixed stars themselves. It would be absurd to suppose that these vast and distant suns could flare up to blazing brilliancy and die down almost to darkness many times in the period of a second, or change their color to every tint of the rainbow within the same interval. The effect of scintillation arises from unevenness in the terrestrial atmosphere through which the starlight passes.

Stars which are distinctly overhead do not twinkle at all; and the glancing, flashing, many-colored appearance of their rays increases in proportion as they are low down towards the horizon, so that their light travels through a greater thickness of our atmosphere. They twinkle more vividly on cold than on warm nights, and when the barometer is high rather than when it is low, as on a clear, frosty night; yet excessive scintillation shows that there is much moisture in the air and may be taken as an indication of approaching wind and rain. It is important, however, not to rely for the identification of stars as distinguished from planets upon the twinkling effect. It is not always clear.

But although conditions of several different kinds tend to increase the unsteadiness of starlight, they all produce this effect by the refractive power of the atmosphere upon light We see a star through many miles of a changeful medium, of which some portions are warmer than others and some more humid than others, so that the fine thread of light from the star to the eyes is broken and split up into its component colors by innumerable tiny movements in the air. The variegated colors are most vivid in the whitest stars, because the light of white stars contains more of the colors of the spectrum than are contained in the light of yellow, orange or red stars. By means of the ingenious instrument the scintillometer it has been found that the changes of color caused by the twinkling of a star take place far more rapidly than can be appreciated by the eye, and are as frequent as fifty to eighty per second.

The reason why the planets shine with a steady light

The reason why planets hardly twinkle, if at all, is to be found in the fact that they are so vastly nearer to the eye than are the fixed stars. Therefore, though they may appear to be mere points of light, they actually present a sufficiently extended disc to neutralize the effects of atmospheric disturbances. Thus, though the rays from each portion of the disc are subject to separate twinkling, the general effect is that of a steady light, because when some rays

fail their place is taken by other rays. A fixed star, on the other hand, however vast it may be, is so distant that it reveals no real disc even though examined through the largest telescope, any apparent disc which may be formed being due either to inherent limitations or to positive imperfections of the instrument.

We are apt to suppose that the stars which are so thickly scattered over the sky are all of one kind, all similar to one another. No impression could be more mistaken. Not only are they of many different kinds, but they show individual differences of extraordinary interest. They have to be studied one by one. Let us take as an example one small region in the constellation Andromeda, which for alphabetical reasons came first in our list. It has three bright stars of the second magnitude, arranged almost in line. One of these, Almaach, the third in order of brilliancy, looks like any other star. In fact, however, it consists of three stars, not merely appearing by perspective at the same spot, but physically related to one another. The chief of these is an orange-colored star, and around this there revolve a pair of stars, tinted green and blue respectively. Not far from Almaach is the radiant point of the Andromedid shooting stars. Close to it also is the vast spiral nebula, visible to the unaided eye, which is traveling toward the earth at a speed of seven miles a second. In the midst of this nebula a bright star came into being in August, 1885, and faded out into nothingness within six months.

Some of the quite unexpected sights of the heavens through a telescope

Or consider the Pole Star, familiar to everyone as marking very nearly the northern point in the heavens. It is a star of the second magnitude at the end of the tail of the Little Bear. This star, whose light is nearly fifty times as great as that of our sun, is closely related to a star of the ninth magnitude near to it, and moreover has two attendant dark stars, one of which revolves around it in about four days, while the other, more distant, takes twelve years for each revolution.

Or, again, the constellation Aquarius shows us no stars even as bright as the third magnitude, but on looking into it with the telescope we find a double star, the pair revolving round one another in about sixteen hundred years; a magnificent globular cluster of stars like a swarm of glittering bees; a pale blue nebula; and other equally varied celestial objects.

The bewildering variability of stars, great and small

In Aquila, again, a constellation which is traversed by the Milky Way, we find a variable star whose light alternately gleams out and is cut off through a constantly recurrent period of seven days. In this same constellation have arisen at different times three "new stars" of exceptional brilliancy, the most recent of which is fully described later on.

In Auriga, the mighty star Capella, which is a hundred times as bright as our sun and rushing away from us at the rate of 19 miles a second, is found to consist of two vast luminaries revolving round one another in one hundred and four days. Another pair of stars in the same constellation revolve round one another in four days; and yet another star varies in brilliancy with bewildering and unaccountable irregularity.

The star Beta Orionis is a prodigious sun having a luminosity 13,000 times that of our own sun. In Canes Venatici, the Hunting Dogs which pursue the Great Bear, the chief star appears to the unaided vision as a mere speck of light; but the telescope shows that this speck consists of two great suns, one yellow and the other lilac.

The wonderful variety of the stars, seemingly inexhaustible

The variety of the stars is inexhaustible. Sirius, the Dog Star, in the constellation of Canis Major, is a bright white luminary which has given the name of Sirian stars to many distant suns of similar color and constitution. Sirius was worshiped by the Egyptians as the star sacred to Isis, and was dreaded by the Romans as ruling the Dog Days, or greatest heats of summer.

The innumerable double stars, and their complicated movements

In Capricornus the chief star can be made out, by unaided vision, to be a pair of stars; but the telescope shows that one of these consists of two stars and the other of three, all five of them moving in close relation. It is evidently a mistake to regard our own sun as a pattern of all stars; it is of one kind among many others, and its position is perhaps isolated in an unusual degree.

Double stars of all kinds are innumerable, and the periods of their revolutions vary without limit. Every constellation shows examples of them. Thus in Cassiopeia, the bright constellation shaped like the letter W between Andromeda and the pole, we find a double star revolving once in two hundred years; and the chief star of Centaurus is a pair revolving once in seventy-nine years, the two members of the pair being twenty-three times as far apart as our earth is distant from the sun. This pair, Alpha Centauri, are our nearest neighbors in space, their light taking only four years and four months to travel to the earth.

The constellation Cepheus is of interest, because its principal star will be the Pole Star after five thousand years from now. Cetus, the Whale, besides having many brilliant nebulæ, includes the wonderful star Mira Ceti, which was the first periodical star to be discovered; its changes recur with some irregularities in about three hundred and thirty-one days, during which time it emerges from dimness to great brilliancy, and fades away again. Corona Borealis, the Northern Crown, between Boötes and Hercules, has a star which is partially eclipsed every three and a half days, another which varies greatly in brilliancy at quite irregular intervals, and three binaries, or double stars.

It is easy to learn the principal constellations with the aid of a star map and a few evenings, at different times of the year, spent in studying the sky. A precise knowledge of all the groups and of their intricate boundaries is, however, unnecessary for the layman.

The mapping and cataloguing of the stars by the use of photography

In former days stars were designated solely according to their constellation, and this is still done to a large extent; but the smaller stars are now known principally by their numbers in certain star catalogues, which give their right ascension and declination, analogous to the longitude and latitude of terrestrial geography, or their relation in the heavens to other stars whose situation is well known. An immense amount of labor has been given to cataloguing the stars, and the precise position and magnitude of over half a million stars are now recorded and available for reference. This work has been largely done by photography, which becomes every day more important in astronomical work. The great chart of the heavens, prepared by collaboration in various parts of the world, involves the exposure of twenty-two thousand photographic plates so as to cover every part of the sky.

The unread maze of heavenly movement that will be deciphered some day

The determination of the precise position of every star has become much more important since it has been discovered that the stars are drifting in various directions and at various speeds, and are moving in some cases more swiftly than the earth in its orbit. Thus Barnard's star drifts through more than ten seconds of space every year, and several others move at speeds approaching this. Arcturus has a yearly motion of over two seconds, and Sirius of more than one second; and these speeds, though they make but little annual difference in the star's apparent position in the sky, answer to tremendous actual velocities, reaching in some cases to hundreds of miles per second. Even those stars which at present seem to us to be at rest are doubtless really in motion, their apparent fixity being due to their almost unimaginable distances from us. Moreover many stars are combined with others in these movements, showing signs of vast systems at whose nature we can hardly guess.

MOUNTAIN STOREHOUSES

The Great Ranges of All the Continents and the Solitary Peaks

EFFECTS ON NATURE AND THE MIND OF MAN

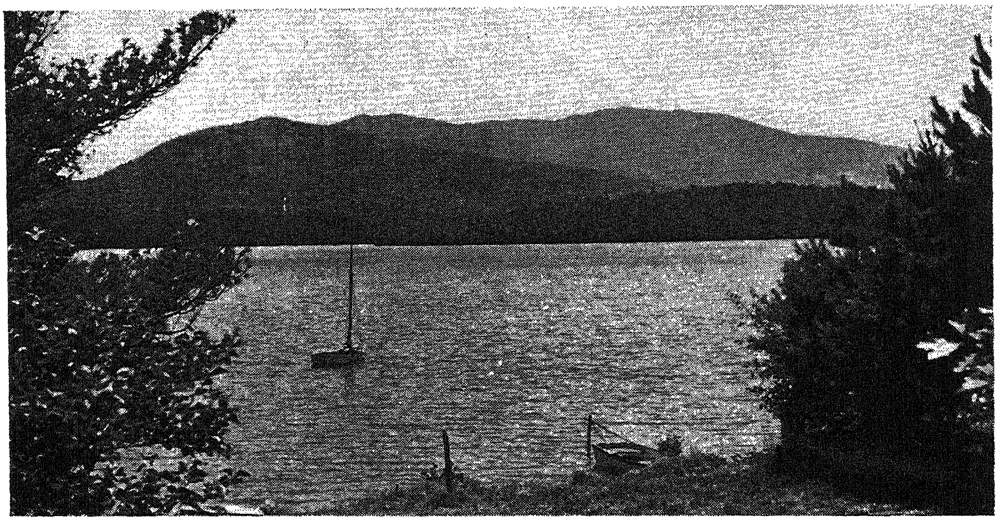
TO the unscientific mind mountains are symbols of immensity and immutability, and men at all times and in all lands have regarded them with reverence, awe and superstition. On Mount Olympus were throned the gods; on Parnassus dwelt the Muses; on Mount Etna were intrenched the Titans; on Mount Hira, Mahomet conceived his religion. Further east still we have the sacred mountain of Fujiyama, in Japan; while on Mount Meru sat the gods of India.

Even in modern, matter-of-fact times mountains arouse sublime emotions. Thousands go to the Canadian Rockies, to Norway and Switzerland, not merely to breathe the mountain air, but also to get spiritual refreshment from the mountain scenery.

Every poet, every painter, has been inspired by the mountains, and some of the noblest pictures in art and some of the finest passages in literature have been born ot the mountains. Were the earth flat it might be beautiful, but it would have much less grandeur and much less sublimity. Ruskin in a fine passage imagines a beautiful flat country suddenly becoming mountainous He imagines a great plain, "with its infinite treasures of natural beauty and happy human life, gathered up in God's hands from one edge of the horizon to the other like a woven garment, and shaken into deep falling folds, as the robes droop from a king's shoulders; all its bright rivers leaping into cataracts along the hollows of its fall, and all its forests rearing themselves aslant against its slopes, as a rider rears himself back when his horse plunges; and all its villages nestling themselves into the new windings of its glens; and all its pastures thrown into steep waves of greensward, dashed with dew along the edges of their folds, and sweeping down into endless slopes, with a cloud here and there lying quietly, half on the grass, half in the air; and he will have as yet, in all this lifted world, only the foundation of one of the great Alps. And whatsoever is lovely in the lowland scenery becomes lovelier in this change."

Indeed, it would almost seem as if the mountain scenery affected the character of the people who inhabit mountainous districts, for mountaineers are notably brave, vigorous and independent. Probably, however, the highland character is the result of struggle with an adverse and stringent environment, rather than the result of intercourse with the grand and sublime in nature. Even the tourist realizes that the mountains are not merely to be admired, but also to be conquered. Difficulties and dangers must always attract the combative spirit of man; and though the conquest of a Mont Blanc or a Matterhorn may to some seem to be waste of energy, the exercise of strength, courage and patience involved in mountaineering braces and invigorates the sinews of the mind as well as the muscles of the body.

But, in the first place, what is a mountain? At what height does a mound become a mount? That is a question that each land must answer for itself, for it is largely a matter of comparison. A small hill in a flat country, arising abruptly from the plain, may seem a veritable mountain to the dwellers on the plain.

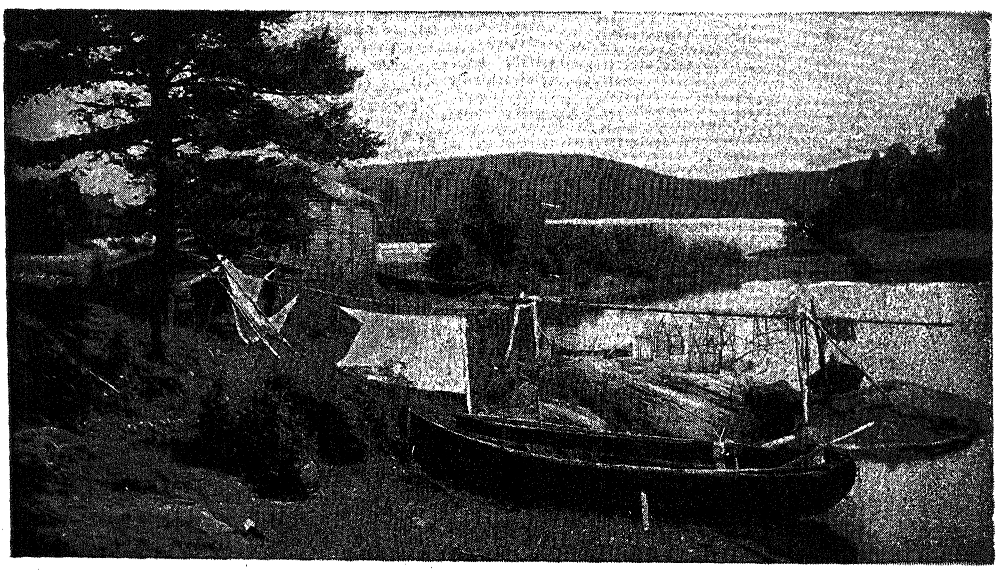


Philip Gendreau

Mount Monadnock, in New Hampshire. It has given its name to the type of hill called a monadnock.

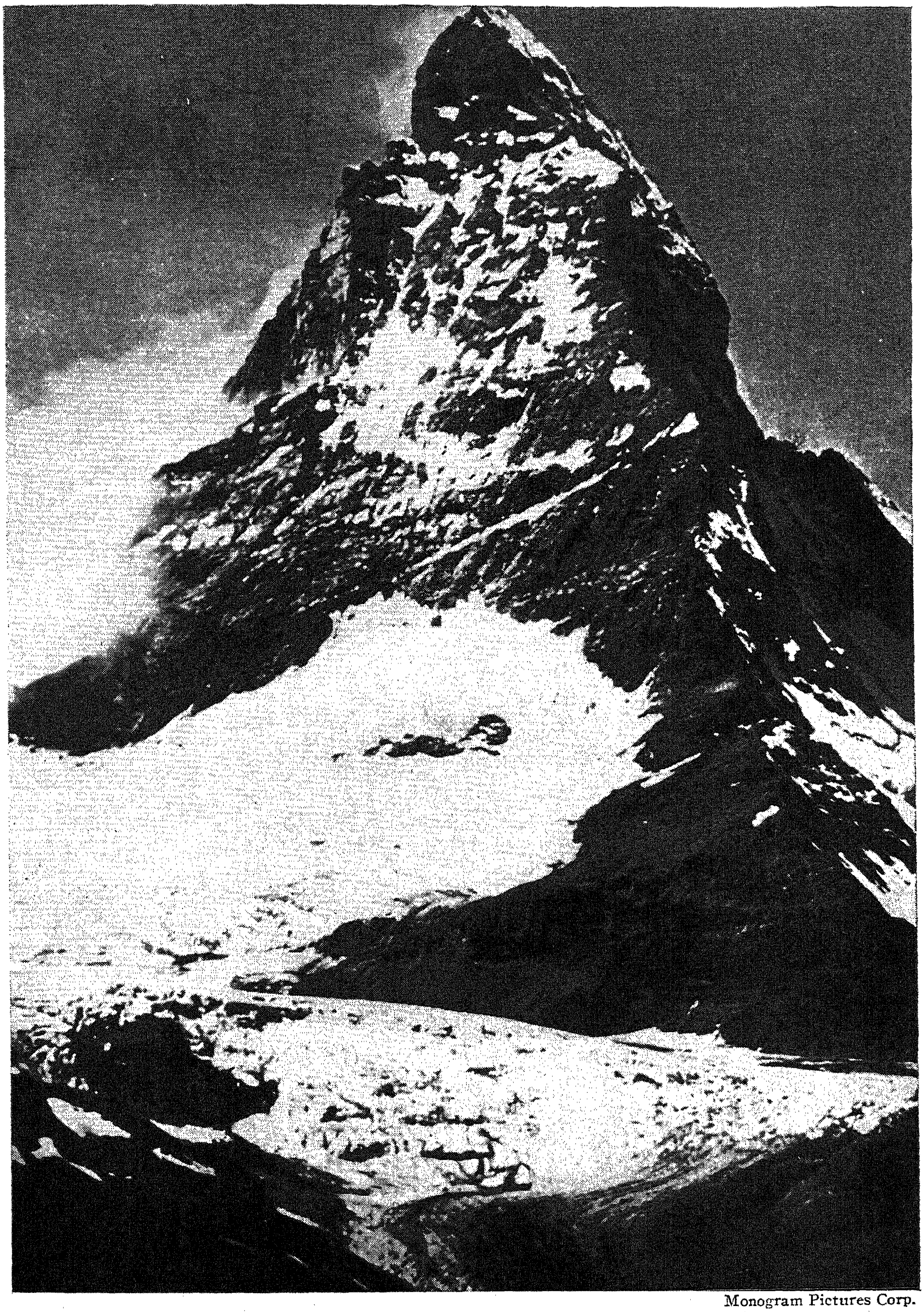
Thus, as Reclus points out, a hill only 780 feet high which rises from the level plains of Lower Pomerania impresses the inhabitants so much that they have named it the Mountain of Hell, while a smaller hill in Denmark but 557 feet high is named by the cheerier Danes the Mountain of Heaven. In a general way, however, to deserve the name, mountains must be some thousands of feet in height.

As a rule, the higher mountains of the world are congregated into groups, and are arranged linearly in ranges and chains. Thus we have the Rockies, the Pacific ranges, the Alps, the Apennines, the Andes, the Himalayas. But, in some instances, a high mountain stands in splendid isolation, like Roraima (8,740 feet) in Venezuela, and, 50 miles away, Mount Kukenaam (over 8,500 feet). These isolated hills are



The Mountain of Heaven, the highest elevation in Denmark, is really a hill, only 557 feet in height.

A STERN SENTINEL OF THE ALPS

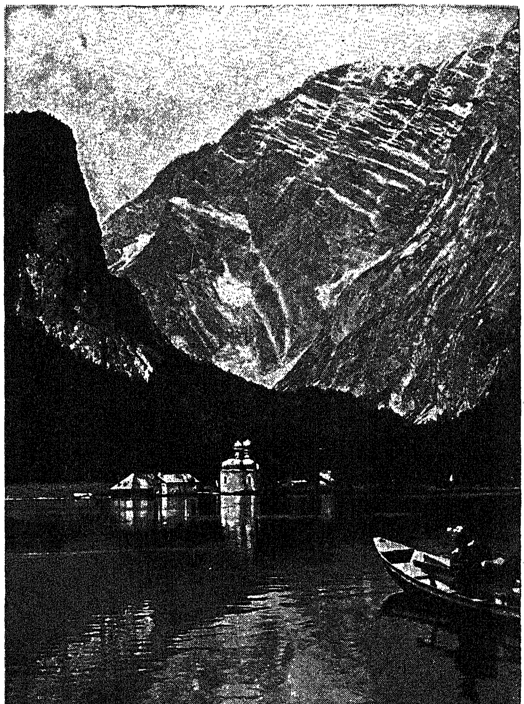


Monogram Pictures Corp.

The Matterhorn (14,780 feet), in the Pennine Alps, is on the Swiss-Italian border, near Zermatt.

colossal earth pillars which resisted the eroding waters that cut down the surrounding country. They are called "monadnocks" in this country, after the mountain of that name in New Hampshire. Mount Wachusett in Massachusetts is of similar formation. Other isolated mountains, such as Vesuvius, Fujiyama and Stromboli, are of volcanic origin. But these solitary peaks are the exceptions, and most mountains are congregated into mighty communities. When we examine the great mountain communities we notice at once that their arrangement is markedly linear. The Alps run in ranks east and west, the Himalayas and the Pyrenees also run east and west, while the Andes, Apennines and Rockies run north and south.

The ranks, of course, are manifold; and though most of the valleys correspond in direction with the linear extension of the mountains, there are numerous passes and transverse valleys that interrupt the linear continuity of the ranges. In the Alps there are many hundreds of distinct valleys; in the Canton Grisons alone there are about five hundred, forming a regular labyrinth.



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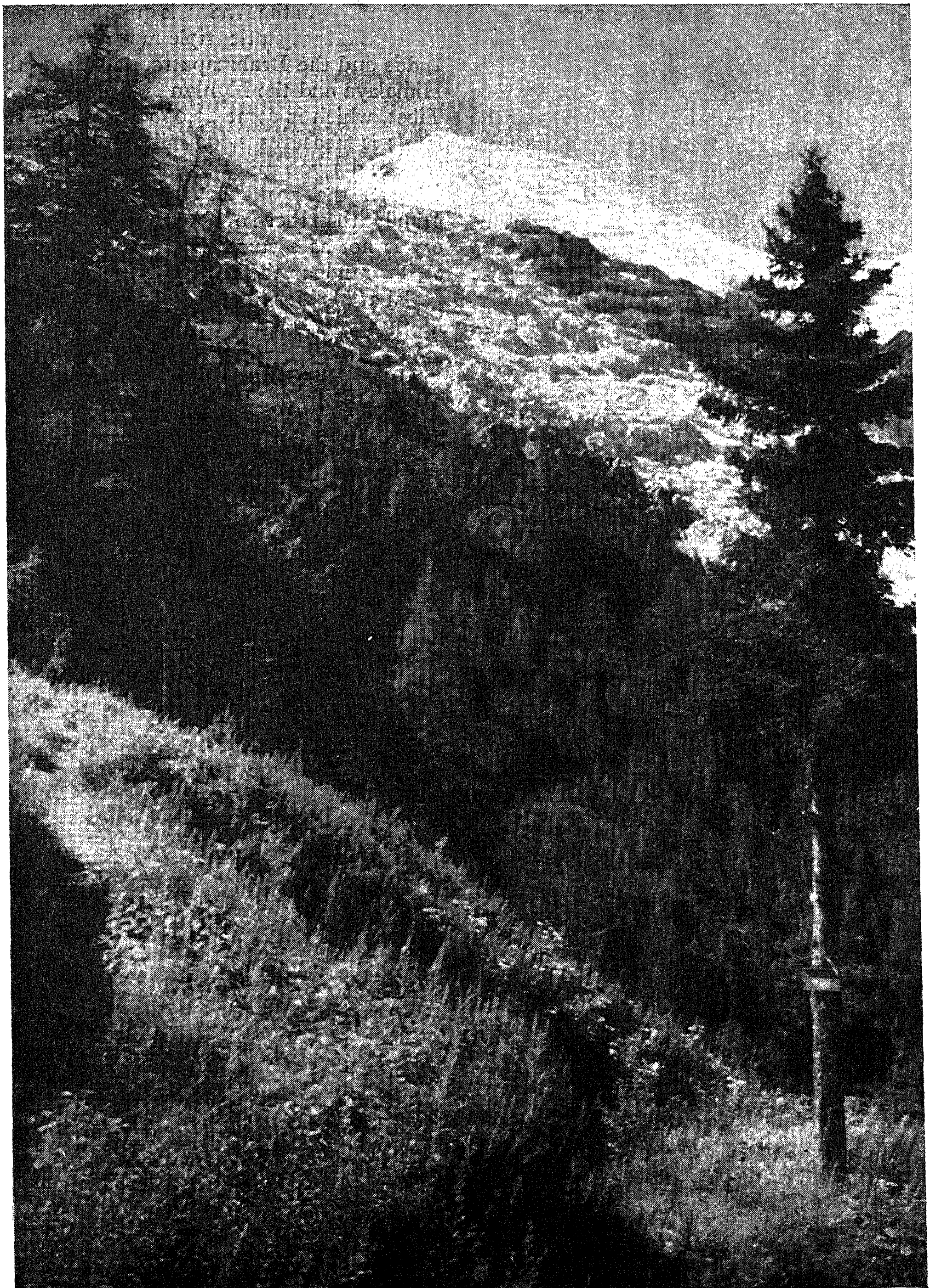
THE GREAT WATZMANN, IN BAVARIA

Let us look for a moment at the height and disposition of some of the great mountain ranges. The Pyrenees run between France and Spain, forming a great mountainous barrier between the two countries. From a principal double rampart of mountains running east and west, transverse mountain chains running north and south are given off, and these transverse chains give off secondary chains at right angles to themselves, and more or less parallel to the principal rampart, the whole mountain system accordingly somewhat resembling the frond of a fern. Very few, if any, of the great mountain ranges of the world can be analyzed into such a simple system. Most of the peaks of the Pyrenees are sharp and pointed, and the general effect is a serrated or dentate ridge. The average height of the peaks is almost 8000 feet, which is about 300 feet more than the average height of the Alps; but the Pyrenees are less striking than the Alps, because none of the peaks much outsoar the others.

The Alps are a much more labyrinthine and complicated series of mountains than the Pyrenees. Though the general trend of the range is east and west, its diversified branches are very numerous, and it can be divided into many more or less distinct systems, each with characteristics of its own. The central mass is the St. Gothard group, from which all the principal chains radiate, but the most magnificent group is the mighty rampart of Monte Rosa, whose peaks all exceed 13,000 feet, Monte Rosa itself reaching 15,217 feet. Mont Blanc, the highest mountain of Europe, is 15,781 feet high, or rather was that height until the recent avalanche brought down a small portion of its pinnacle, but the average height of the mountains of its group is only 12,657 feet. Though the average height of the Alps is not so great as that of the Pyrenees, yet they are a much more striking system of mountains, because of the number of mountain giants, such as Mont Blanc, the Jungfrau, the Matterhorn and Monte Rosa, which they contain.

THE MONARCH OF THE ALPS



Screen Traveler, from Gendreau

Mont Blanc, as seen from Chamonix. It is the highest peak in the group called the Mont Blanc massif.

The Himalaya range is the southernmost of a triple rampart of mountain ranges running east and west across Asia, to the north of India. The most northerly of these ranges is the Kunlun, or Kuenlun, Shan; the middle range is the Karakoram. This threefold rampart extends for a distance of 2,000 miles and its breadth in certain places is over 600 miles. The height of the rampart is truly breath-taking. The peaks of the Karakoram have the greatest mean height; next come those of the Himalaya and, lastly, those of the Kunlun. In the Himalaya range there are a great many peaks that are higher than Mont Blanc; Mount Everest (29,200 feet) is almost twice the height of that king of European mountains. Mount Everest, of course, is the highest known mountain in the world. But Mount Godwin Austen (28,250 feet), in the Karakoram, and Kanchenjunga (28,146 feet), in the Himalaya, are not very far behind; while Mount Dhaulagiri (26,795 feet), in the Himalaya, is a quite worthy rival. No other peaks in any other ranges can compete with giants like these; even Aconcagua (23,081 feet), the loftiest peak in the Andes, is quite outtopped.

From this gigantic triple rampart flow the Indus and the Brahmaputra. Between the Himalaya and the Kunlun is the plateau of Tibet, which is some 13,000 feet above sea level; it measures 2,000 miles from east to west and 1,700 miles from north to south. Though the peaks of the Himalaya are grander than those of Switzerland, the scenery is not so picturesque and varied. "In all its grandeur, the Himalaya is uniform, its peaks are loftier, its snows more extensive, its forests deeper, but there are fewer cascades and lakes; there are no pleasant lawns and scattered groves, and we fail to note the picturesque chalets nestling down in the glens, or hanging over the brims of the precipices." Because of the height of these mountains and because they are situated in a land with a warm climate, every climate is represented as we ascend them. First, we have a tropical climate with tropical fauna and flora; then a temperate one, with corresponding animal and plant life; finally, there is a forbidding arctic climate, with perpetual snows decking the mountains.

Screen Traveler, from Gendreau

The Route of the Pyrenees, winding high above sea level amid tall peaks, connects Spain and France.

Since these great ranges run east and west, they put a great barrier between north and south; and since neither north nor south winds can pass the barrier, there is a marked difference in the climates to the north and south of the range. Were the mountains removed, India would be cooler and northern Asia warmer. On the other hand, it must not be forgotten that winds pouring downwards from the snowy peaks must, to some extent, mitigate the heat of the plains of northern India. We shall deal later with descending mountain winds.

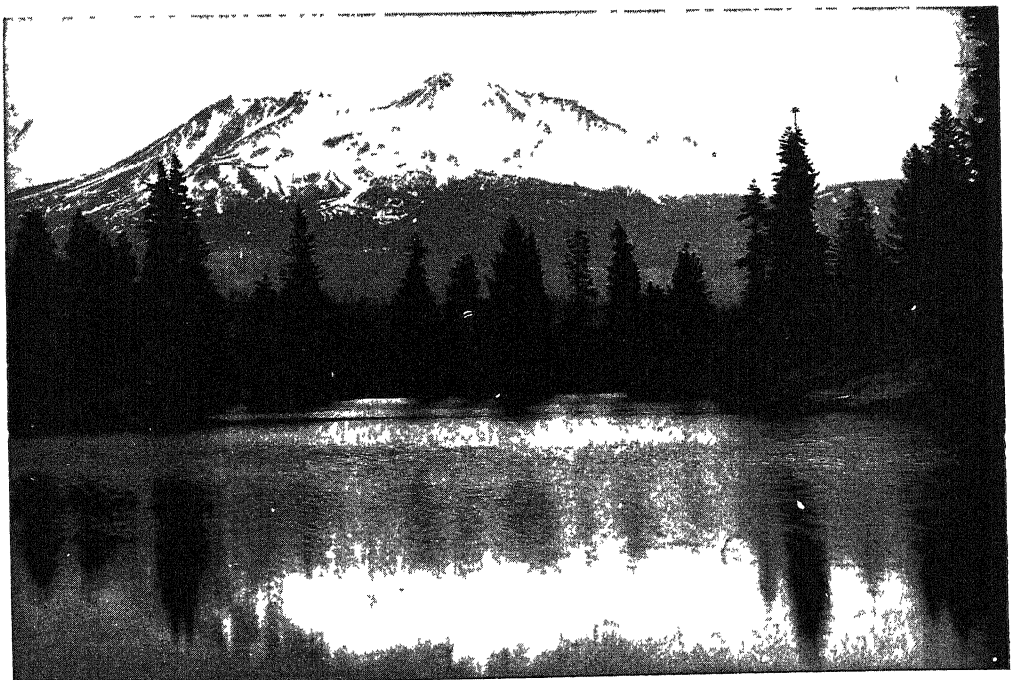
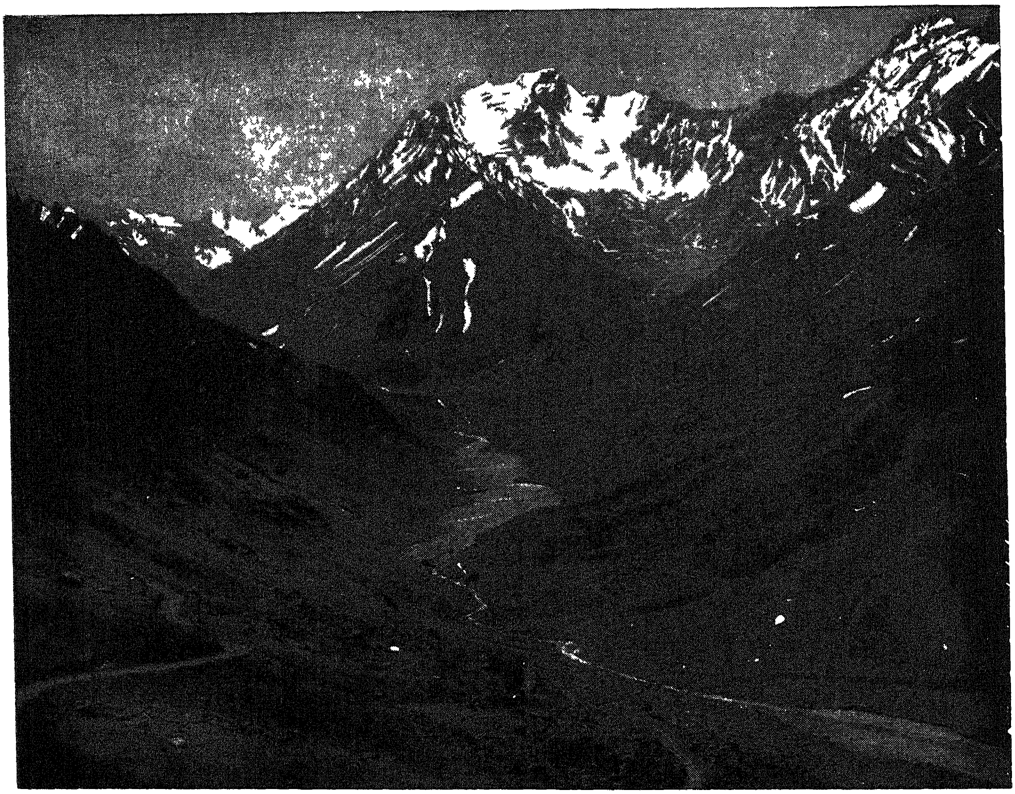


Photo B M DeCou, © Ewing Galloway, N Y.
MOUNT SHASTA (14,380 FEET), A PEAK OF THE SIERRA NEVADA IN CALIFORNIA

In North America we have the Rocky Mountains or the Cordilleran system, forming the major axis of the elevated lands of the western part, extending from Alaska to South America and separated from the Andes by a very low pass in Panama. The ranges near the Pacific are the Cascade and Sierra Nevada in the United States, and the Sierra Madre in Mexico and Central America. West of the Sierra Nevada in California is the Coast Range. The Coast, Cascade and Sierra Nevada ranges are really separate mountain systems though popularly said to belong to the Rocky Mountain system. The eastern chains of this system in the United States are the Rocky Mountains proper. In Colorado alone in this system there are about 40 peaks over 14,000 feet high, the highest in the Sangre de Cristo range being Blanca Peak, 14,310 feet. The highest peaks of the general system are found in the Cascade range, Mount McKinley, 20,300 feet, Mount Logan 19,500 feet and Mount St. Elias 18,101 feet. The Sierra Madre range boasts of two high volcanic peaks, Orizaba (18,300 feet) and Popocatepetl (17,887 feet). The great mountain system of the eastern United States is the Appalachian, running from northern Alabama into New York and probably embracing the New England system. It includes the Alleghanies, the Blue Ridge, the Cumberland, the Black, White and Green Mountains and the Catskills. This system is fairly long but narrow, at no point much over 100 miles wide. There are no very great elevations in the Appalachians, the highest peak being Mount Mitchell in the Black Mountains, North Carolina (6711 feet).

In South America we have the magnificent range of the Andes, the longest and most continuous mountain system in the world. It runs north and south near the Pacific coast for a distance of 4500 miles. Though the average height of the peaks is considerably less than that of the peaks of the Himalayas and Karakorams, and though it contains none that can rival Mount Everest, yet it is the second highest range in the world. Its highest peak, Aconcagua, towers 23,000 feet above sea level, and it includes at least thirteen peaks over 19,000 feet. The height of the range, too, is remarkably consistent. Most of its passes are 14,000 feet high, and the lowest pass in a stretch of 4000 miles is 11,400 feet. The range divides South America very unevenly, its distance from the Pacific being 30 to 150 miles, while in places it is 3000 miles from the Atlantic. North of Aconcagua the range is double, and at one place the double chain incloses a plateau as large as the entire state of Maine. South of Aconcagua the range consists of a single rugged ridge which gradually dwindles as it runs southwards

In northern Africa there is an extensive mountain system, starting near Cape Nun on the Atlantic and ending near the Mediterranean coast The highest peaks of this system are Jebel Ayashi, 14,000 feet, and Tamjurt, 14,500 feet Most of the lofty mountains in Africa are volcanic Volcanic, for instance, are the Cameroons (13,760 feet), Kenia (18,370 fect) Kilimanjaro (19,300 feet). Yet, strangely enough, despite its few mountain chains, the African continent has an average height of 1640 feet — equal to the average height of Asia, with its Himalayas and Karakorams



THE PASS IN THE ANDES IN TUNGURAGUA, ECUADOR, SHOWING THE SOURCE OF THE AMAZON

Having thus glanced at the great mountain chains, let us look for a moment at the uses of mountains. The mountains play a varied and important part in the economy of nature. Firstly and chiefly they focus the mechanical energy of the water lifted into the sky by the heat-energy of the sun

A PEAK IN THE CANADIAN ROCKIES

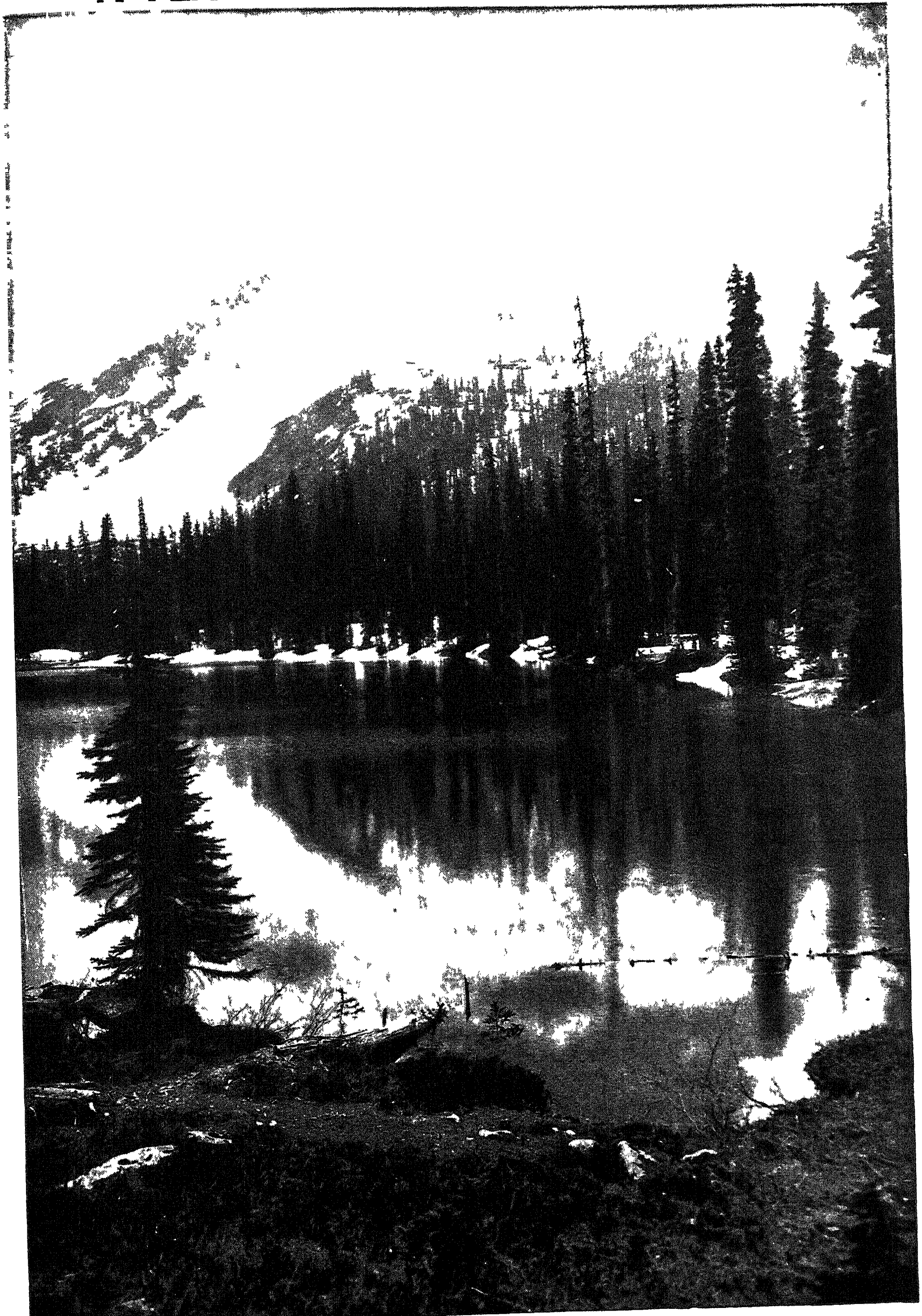
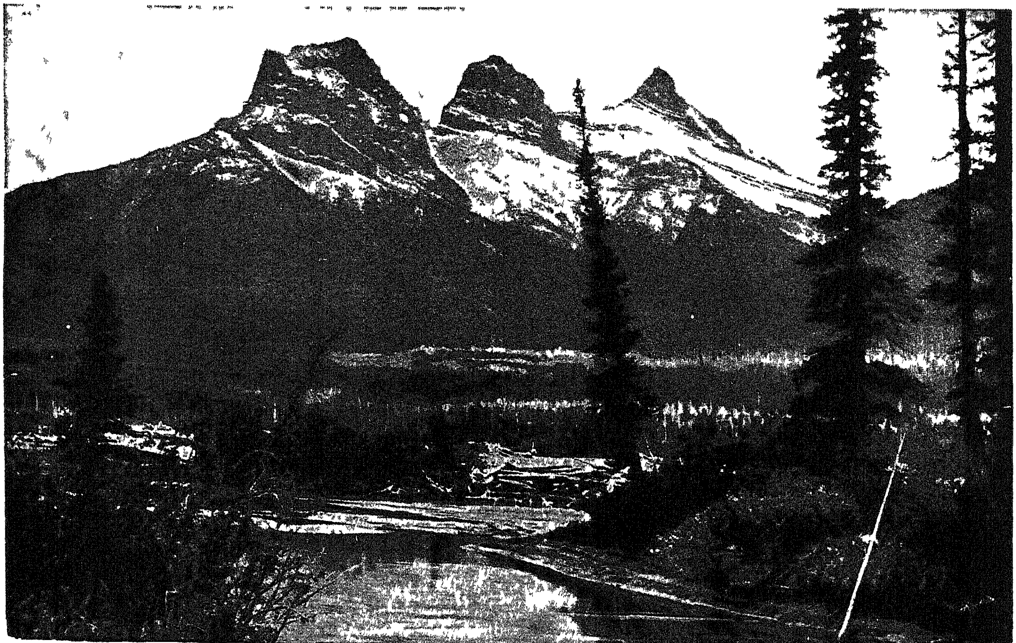


Photo B. M. DeCou, Courtesy Canadian Pacific Railway

MOUNT WAPTA AND SUMMIT LAKE

Now so far as the sun is concerned, the water-vapor would be spread uniformly through the atmosphere over the earth in a more or less indiscriminate way Were the earth flat, the rain would be much more equally distributed; there would not be 500 inches at Cherrapunji and 3 inches at Leh, in India, but about the same rainfall in both places, and most of the variations that at present exist in the geographical distribution of rain would be abolished. Where the hills and seas now are, the rainfall would be less; where the plains now are, the rainfall would be more. Further, a great part of the land surface would be condensed as rain; in the second place, such a wind blowing against the base of any mountain is necessarily deflected upwards into the rarer atmosphere. There it expands; and since expansion means cooling, the air is cooled, and deposits its load of moisture as rain. Not only does the cold mountain cool the air, then, but by directing its course upwards and compelling its expansion it forces the air to cool itself. The tremendous rainfall at Cherrapunji is due not only to the contact of the warm, moist monsoon with the cooler hill-tops, but also to the fact that the monsoon is forced upwards by the Khasi Hills.



IN THE CANADIAN ROCKIES — THE THREE SISTERS OF CANMORE

verted into marshland and bog-land, for owing to lack of declivity drainage would be bad. It is the mountains that focus the rainfall; it is the mountains that concentrate it into certain downhill channels, and thus give it a maximum of mechanical power. Rain from the sky cannot turn a mill-wheel, but concentrated in a mountain torrent it can light a city, or grind corn, or husk cotton-seeds, or synthesize nitrates

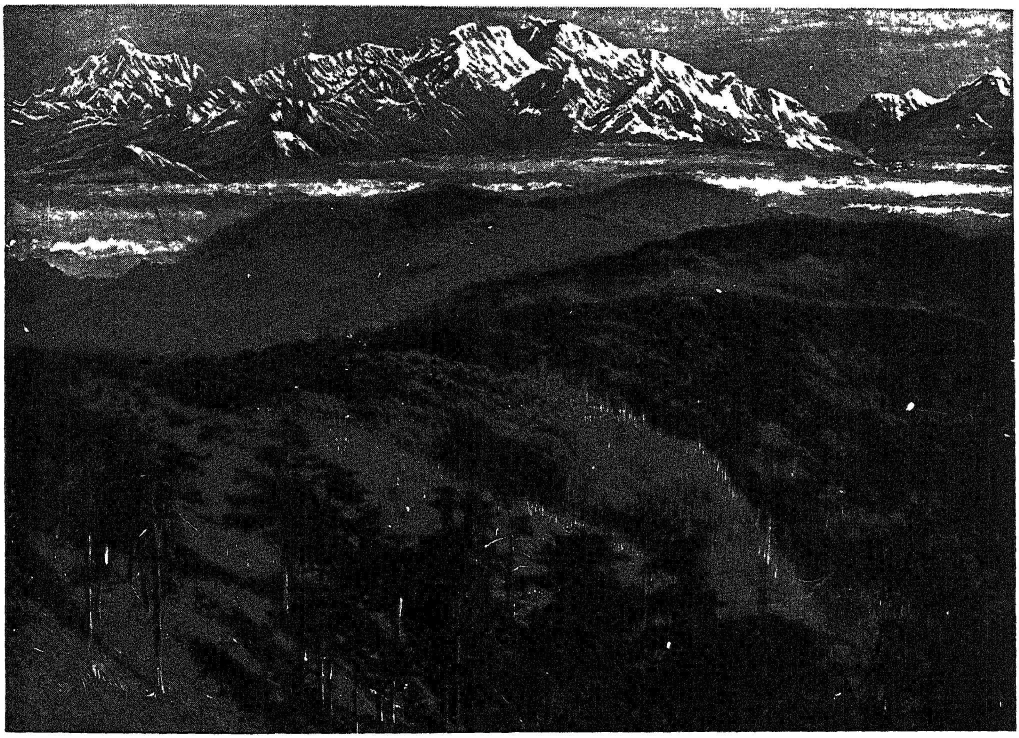
As we have already indicated, mountains gather and give rain in two ways. In the first place, any warm, moist wind blowing against a cold mountain summit is con-

Almost all the rainy places of the world are among the mountains, and most of the arid places of the earth are flat plains The importance of this concentration and differentiation of rainfall is evident at once from a climatic, an agricultural, and a commercial standpoint. Did nature not make rivers for us, we should have, like the fabled Martians, to make canals, or construct colossal systems of aqueducts. We must have our water supply mobile for many reasons, and, if it is to be a source of power, we must have it concentrated in rivers and waterfalls.

It is difficult to realize the amount of energy a mountain can gather simply by collecting rain. The amount of sun-heat required to evaporate sufficient water to cover one square mile to the depth of one inch is equal to the amount of heat produced by the combustion of five thousand tons of coal. The equivalent, again, in mechanical energy of this amount of heat would be sufficient to raise ten million tons to the height of one mile. It is immense solar energy of this sort that mountains seize and concentrate and utilize — energy that otherwise would be dissipated and, in great measure, wasted.

But mountains do more than seize and concentrate this hydraulic equivalent of solar energy; they also sometimes hoard and bank it. All these white summits of the Alps, the Himalayas and the Andes represent an enormous reserve capital of mechanical and chemical power. In winter the balance increases; in summer it diminishes, and the general result is a banking of energy at certain points, with a redistribution of it at certain times, both in the form of rivers of water and in the form of rivers of ice, but through both forms to the general advantage of the lowland world.

Were it not for the Alps, the Po, the Rhone, the Rhine and the Danube would be mere brooks in summer "But for those barren fields of ice," writes Bonney, "high up among the silent crags (of the Alps), the seeming home of winter and death, these great arteries of life would every summer dwindle down to paltry streams, feebly wandering over stone-strewn beds Stand, for example, on some mountain-spur and look down on the Lombardy plain, all one rich carpet of wheat and maize, of rice and vine; the life of these myriad threads of green and gold is fed from these icy peaks, which stand out against the northern sky in such strange and solemn contrast. As it is with the Po, so is it with the Rhine and the Rhone, both of which issue from the Alps as broad, swelling streams; so too with the Danube, which, although it does not rise in the Alps, yet receives from the Inn and the Drave almost all the drainage of the eastern districts."



A DISTANT VIEW OF THE HIMALAYAS, SHOWING MOUNT KUNCHINJINGA

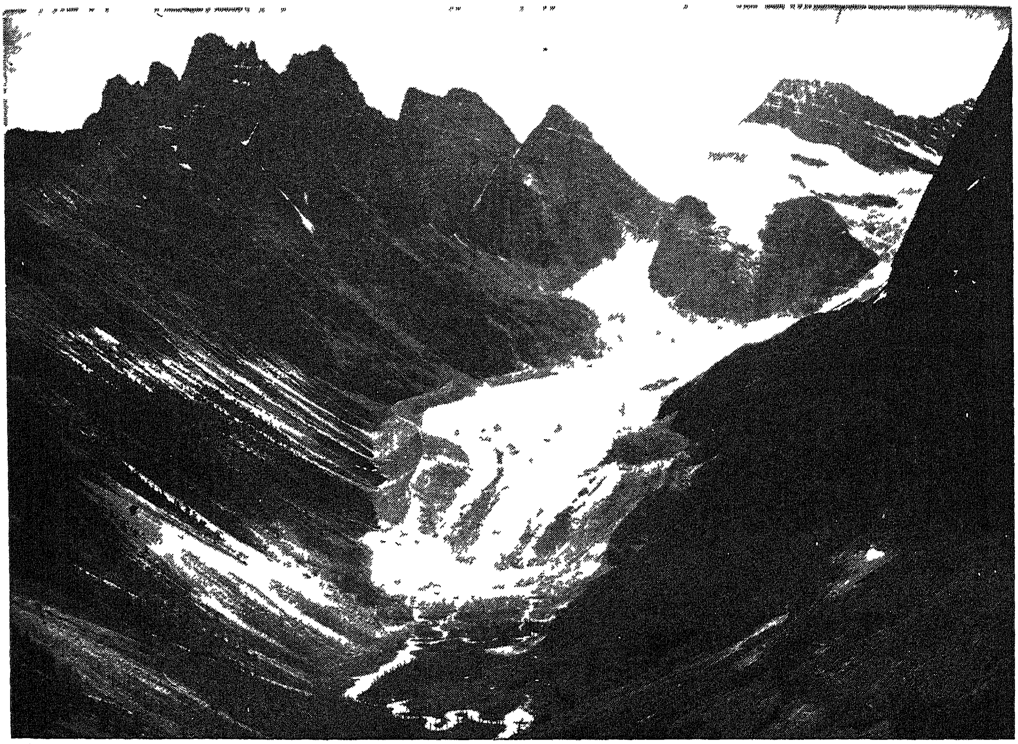


Photo Wide World

BONNINGTON PEAK AND GLACIER, JASPFR NATIONAL PARK, ALBERTA

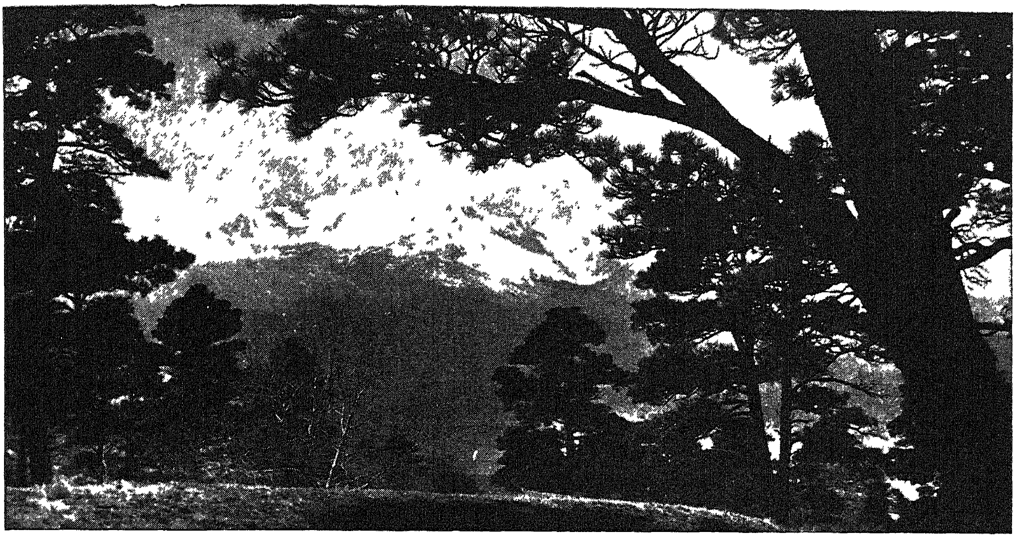
But mountains do not always keep their reserve of water in cold storage; they also hoard it in mountain marshes, peat-beds and bogs The amount of water so kept in reserve, and economically and slowly expended by a process of gradual drainage, may be very great. Some flat mountains in times of rain are simply colossal sponges.

Mountains, then, as makers and conservators of water-force, play a most important part in nature; they are in a sense at once the mainspring and the controlling lever of the greater part of the water-energy of the world.

But they can make rivers only at the expense of their own substance. Much of the great energy they render available goes to the destruction of themselves. Every brook brawling down the mountain takes part of the mountain with it, no matter how hard and durable the rock may be.

Yet this destruction of the mountain is the salvation of the world as the habitation of living things; the debris of the rocks is the food of all the forests and gardens and meadows of the world. The rivers and glaciers wear down the mountains to make soil for the roses and cabbages. The most fertile lands in the world — the delta of the Nile, the Imperial Valley of California — are made of the wear and tear of mountains brought down by rivers, great and small.

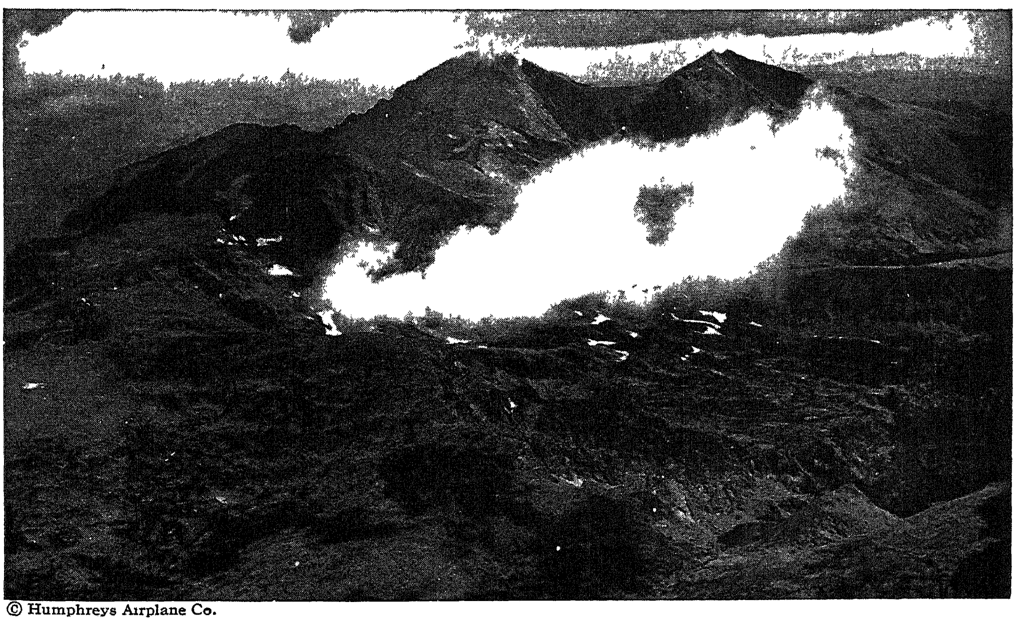
Mountains, then, concentrate and apportion rain and make soil. Further, they promote the circulation of air, through the difference of temperatures at their bases and summits, and the rapid changes of temperature to which their peaks are subject. During a sunny day the top of a mountain is more heated than the plain below, and hence during the day there is an ascending current of cooler air from the plain to the mountains. At night, again, the hilltop cools more rapidly than the plain, and so there is a descending current of cool air from hilltop to plain. The mistral so much dreaded on the Riviera is a torrent of cold air pouring down from the summits of the Cevennes and Maritime Alps. The bora of the Adriatic, and the tramontana negra or black norther of



PIKES PEAK, WITH A FRESH MANTLE OF SNOW

Greece, the "Majorcan carpenter", the black bise of Algeria, have similar origin In the Himalayas the updraught is very marked, and blows from 9 A M. to 9 P M. It is rather interesting to notice how even unscientific men have discovered this regular alternation. The hunter will build his fire below his tent at night, and above his tent in the morning, so that the smoke of the fire may blow away from the tent; and in certain valleys the inhabitants build their huts and houses on raised ground, to be above the river of cold air which flows down the mountains on winter nights.

All these functions, then, in the economy of nature mountains play; and in addition they form natural barriers between nations, and between flora and fauna — barriers which have great historical and biological, as well as panoramic, significance.



LONGS PEAK AND MOUNT MEEKER, ROCKY MOUNTAIN NATIONAL PARK

THE HEAD AND MOUTH PARTS OF THE FEMALE MALARIA MOSQUITO, ANOPHELES

The mouth-parts are here shown separated but in their natural state they are all perfectly arranged in the proboscis like a set of surgical instruments. The upper lip is seen on the left and the lower on the extreme right between these are the thread-like lancets and two hairy palps. The whole group, when closed, constitute the proboscis—highly magnified. In the top right hand corner of this picture is shown a tip of one of the lancets magnified in area 25,000 times, this photograph showing the barbs.

These photographs are by Mr. J. J Ward

MAN AND THE MOSQUITO

The Story of the War Waged by Men of Science of All Nations Against Malaria

DEFEATING AN ALLY OF BARBARISM

WE have already seen that the powers of life have manifested themselves, above all, in the insects, with their instincts, at the head of the invertebrate world, and in man, with his instincts and his intelligence, at the head of the vertebrate world. No actual "struggle for life", of any importance, exists between man and the highest insects, the social hymenoptera, such as the bees. But among other insects we now begin to find the chief effective enemies of man, apart from such microbes as that of tuberculosis. Further, we find that the insects which man has most to fear are not deadly in themselves, though undoubtedly parasitic upon his blood, but injure him, as it were, accidentally, because of certain minute parasites which make hosts for themselves, both of man and of the insects. Thus the "struggle for life" and the "balance of nature" take on most complicated forms, which we require to unravel, first for their inherent interest; and second, because our life and death, health and disease, success and failure (as in trying to sever continents), are so intimately concerned.

Here, again, Louis Pasteur was the pioneer. In the 'seventies of the nineteenth century he established in Paris the school of thought and practice which led the way to conquests of which even he could scarcely dream; and just as Sir Frederick Treves has said that the late Lord Lister, the greatest of Pasteur's disciples, won for Japan her war with Russia, as we shall see, so it may be said that Louis Pasteur dug the Panama Canal. Let us trace the sequence of events.

It was the German pupil of Pasteur, Robert Koch, who, as we have seen, discovered the microbic parasite of tuberculosis, a discovery from which is now surely proceeding the extermination of that disease. All parts of the civilized world sent their representatives to the Pasteur Institute in those days, but France herself was not lacking. Thus Charles Louis Alphonse Laveran, a French army surgeon—as he then was—took the opportunities which were before him in North Africa, and began to hunt the blood of malaria patients, in the hope of finding some causal parasite, such as his teacher was finding in other diseases.

Laveran's work was not unrewarded, and he duly found a parasite which was invariably present in all cases of malaria. The Germans had previously noticed that a certain kind of pigment was deposited in the liver and spleen of persons dying of malaria. When Laveran in 1880 discovered a parasite in the red blood-cells he noted that this same pigment was formed in the parasite. This at once cast suspicion upon the parasite as being the cause of the malaria and the pigment. Golgi, an Italian, verified Laveran's discovery, and in 1885 this Italian showed that the malarial chill, fever and sweat occurred at the time when the parasite "sporulated". When it was noted that malaria and swampy areas existed together, the mosquito's connection with the disease was suspected, but it was not until 1895 that the mosquito was definitely found to be the carrier of the disease.

A French physician's discovery of the hæmatozoön of malaria

Laveran's Algerian work, with his result, was published in 1880 in his "*La Paludisme*". Paludism (that is, marsh-ism) was, and is, indeed, the technical name for malaria, indicating its almost invariable origin in connection with marshes. But this book gave us a new conception of the disease, and of the appropriateness of its names. The word "mal'aria" is obviously nothing but Italian for "bad air". Now, marshes, especially at night, beget a "dangerous night-air", or "miasm", which may seem to be the cause of the illness which often attacks dwellers on marshes, just as "sewer gas" was thought to be the cause of puerperal fever, typhus and typhoid. But Laveran showed us that, in fact, the disease "ague", malaria so-called, or paludism so-called, is not due to bad air, is not due to marshes, but is due to a living parasite which multiplies in enormous numbers in the blood of the patient, destroys his red blood-cells, produces poisons, and so causes the well-known symptoms of the disease.

The parasite, illustrated on page 3326, is not a plant, like the bacilli of tuberculosis and so many other diseases, but a minute animal. As it inhabits the blood of man, it may be spoken of as a hæmatozoön, or blood-animal. It is one of the great group of animal forms which the zoölogists call the "protozoa", or "first or simplest animals", the humblest group that they know.

The life-cycle within man of the two varieties of malarial parasite

It occurs in the blood of man in various shapes and states, some of which are specially characteristic of one type of malaria, and others of other types. For the acute attacks in this disease occur at different intervals in different cases, so that we used to speak of "quotidian fever", "tertian fever", "quartan fever", according to the number of days elapsing between the febrile attacks.

We now know that these differences depend upon the particular variety of parasite with which the patient has been infected, and that in certain types of the disease the symptoms are due to a double infection with two varieties of the parasite, each going through its own life-cycle at its own rate The generations follow one another with extreme and, for the unfortunate host, disastrous rapidity; and the birth of each new generation of young forms in the blood of the patient appears to coincide with the production of certain poisonous substances, which show their power by the production of a fresh attack of shivering and fever for the unhappy victim.

It has further been found — to complete our initial account of the parasite itself — that this humble organism, contrary to all expectation and previous zoölogical experience, is sexual, or, rather, that its life-history comprises a sexual stage. Two forms, male and female, each consisting of only a single cell, can be identified, and, as we shall see, this occurrence of a sexual phase in a complete life-cycle of the parasite, which cannot be completed in the blood of man, renders an intermediate host necessary for the continuation of this race of minute organisms.

Parasite that causes the greatest amount of illness and the drug that checks it

The malaria parasite has a wide distribution upon our planet. The disease it causes is the most common, though tuberculosis is the most deadly, to which man is subject. Undoubtedly this parasite causes more illness than any other. If we include certain of the lower animals within our purview — as is well worth while, we shall discover — we find that closely allied forms of parasites, cousins, so to speak, of our own, inhabit the blood of other creatures, causing similar symptoms in them. Conspicuous in this relation is the avian malaria which attacks various species of birds, and which helped us to discover what is so essential for any success against malaria.

Perhaps one should not say "any success", for that is to do less than justice to the wonderful drug quinine. The bark of the cinchona, often called "Jesuits'

bark", in honor of those who first popularized its use, contains various peculiar alkaloids, and. above all, the one called quinine, which can enter the blood, when a preparation of the bark, or of the alkaloids themselves, is swallowed, and can there kill the malaria parasite, in the great majority of cases. That drug has saved untold myriads of lives, and has very valuable uses against malaria even today. During World II a shortage of quinine led to the production and development of two drugs, atabrine and totaquine, which proved useful in mild cases, and as a prophylactic agent.

How, then, does the parasite get there, and what part do the marshes play in "paludism", and the air which comes from them at night in "malaria"? The association is unmistakable, and has been recognized from the most ancient times.

First records of the truth concerning the origin of malaria

A few wise men had "guessed" the truth, long before the parasite was known. In an Eastern work on medicine, fourteen hundred years old, it was stated that malaria is carried by flies or mosquitoes. Early in the nineteenth century an American doctor blamed mosquitoes for both malaria and yellow fever. But the Frenchman Dr. Beauperthuy is the real pioneer. In 1853 he sent an essentially complete account of the truth to the French Academy of Sciences, asserting that mosquitoes inoculate man with malaria and yellow fever; that these diseases are not contagious; and, as for marshes, that "marshes do not communicate to the atmosphere anything more than humidity, and the small amount of hydrogen they give off does not cause in man the slightest indisposition in equatorial and inter-tropical regions renowned for their unhealthiness. Nor is it the putrescence of the water that makes it unhealthy, but the presence of mosquitoes." Thus the French doctor's guess was forty-two years ahead of its proof, and never has a scientific proof more completely verified the guesses of a man of patience and genius than in this instance.

Ignoring other steps in our knowledge, we come to the notable suggestion and demonstration, made by the English physician Patrick Manson, in the early 'eighties, that a certain worm disease, called filariasis, is transmitted by the bite of the female mosquito, since it was found that the mosquito is the "intermediate host" of the parasitic worm in question. Briefly, it suffices to say that many creatures, such as the filaria (and now, as we know, the malaria parasite), pass the cycle of their lives in two stages — the first in an animal of one species, and the second in an animal of another.

Manson's study of the worm that is carried to man by the mosquito

Thus, the trichina worm lives in the pig and in man, as Virchow first showed in Germany; and every succeeding step in our knowledge has added to the importance of these peculiar life-cycles, in the case of many parasites — above all, where one of the hosts is man.

We may feel little interest in filariasis, but the worm which causes this disease is a curse of the tropics, infecting in some parts of China, for instance, half of the population. Early in the 'seventies, Manson, who was then in Formosa, tried to puzzle out the facts. Another observer had traced the disease to the tiny worm, the filaria. Manson went back to China, and continued his study and speculation. What could possibly convey this worm to the blood? Might it not be something capable of piercing the skin, taking some blood, containing the worm, and then transferring it to another person? The only likely or imaginable agent was the mosquito. So he made a test, getting a Chinaman who had filariæ in his blood to be bitten by mosquitoes, and then examining them The filariæ were found in the stomachs of the mosquitoes, and not dead, but alive and active.

Finally, Manson traced certain changes and peregrinations of the filariæ, until they reached the sheath of the mosquito's proboscis, whence they were injected into the blood of a fresh patient. This shows us finally that "man harboring the para-

site is the reservoir, the mosquito is the carrier of the parasite. . . . The parasite passes part of its existence in man, and part in the mosquito; both man and the mosquito are necessary for the complete development of the parasite. Therefore, if the mosquito is destroyed, the life-cycle of the parasite is destroyed, and the disease must of necessity cease."

Ross's discovery of how mosquitoes convey malaria from man to man

In 1895 Major Ronald Ross discovered the parallel fact for malaria. "A water-breeding mosquito sucked, not decomposed vegetable or animal matter at the marsh, but the blood of a man suffering from malaria, in which there were parasites in abundance. The parasites sucked in with the meal of blood underwent further development in the mosquito — *i.e.*, infected the mosquito; and then when the *infected* mosquito, which had now become the *carrier*, bit man, it *infected* him." Simple, is it not? But this true theory of such diseases built the Panama Canal and is changing the face and destiny of the world.

After discussion with Manson, Major Ross went back to India, and began hunting for Laveran's parasite in the bodies of mosquitoes. Nothing came of it. But at Secunderabad he noticed a special kind of mosquito, not the ordinary, too familiar *Culex*, and it occurred to him that he must systematically look for the parasite in every kind of mosquito that ever bit man. Working eight hours a day at his microscope, under cruelly difficult conditions of heat and persecution by flies, he persisted, and was finally rewarded.

Ross's researches respecting the presence of malarial parasites in mosquitoes

"On August 20th I had two remaining insects, both living. [They were insects which were known to have bitten malarial patients.] Both had been fed on the 16th. I had much work to do with other mosquitoes, and was not able to attend to these until late in the afternoon, when my sight had become very fatigued. The seventh dapple-winged mosquito was then successfully dissected. Every cell was searched, and to my intense disappointment nothing whatever was found until I came to the insect's stomach. Here, however, just as I was about to abandon the examination, I saw a very delicate circular cell, apparently lying among the ordinary cells of the organ, and scarcely distinguishable from them. Almost instinctively I felt that here was something new. On looking further, another and another similar object presented itself. I now focused the lens carefully on one of these, and found that it contained a few minute granules of some black substance, exactly like the pigment of the parasite of malaria. I counted altogether twelve of these cells in the insect, but was so tired with work, and had been so often disappointed before, that I did not at the moment recognize the value of the observation. After mounting the preparation, I went home and slept for nearly an hour. On waking, my first thought was that the problem was solved, and so it was."

Experiment with infected mosquitoes

He traced the development of the parasite within the mosquito, and by means of special staining he showed how the parasite produces spores, and traced their course. Here are his words. "The exact route of infection of this great disease, which annually slays its millions of human beings, and keeps whole continents in darkness, was revealed. These minute spores enter the salivary gland of the mosquito, and pass with its poisonous saliva directly into the blood of man. Never in our dreams had we imagined so wonderful a tale as this."

For this discovery, in especial, Ross received the Nobel prize for medicine some years later. Meanwhile his work had been confirmed. In 1900, mosquitoes were conveyed from the Campagna, in Italy, having first sucked up a meal of blood from a malaria patient. Under the direction of Manson, two gentlemen, one of them his own son, neither of whom having ever been out of England, offered themselves to be bitten by these mosquitoes.

Young Manson contracted malaria, and parasites of the same type as in the Italian case were found in his blood. He was "cured" with quinine, but had a recurrence about a year later — some parasites having been in hiding in his body meanwhile.

This experiment demonstrated that a person could contract malaria where epidemic malaria did not exist, provided that he was bitten by *infected mosquitoes*. Ross had, therefore, worked out the whole story. The mosquito was the carrier of malaria *from man to man*. Malaria had no connection with miasms. The reason why malaria was associated with marshes and water was simply that mosquitoes bred there.

Until this discovery man's sole weapon against malaria was quinine. This drug usually cures, and it may be used so as to prevent, being taken regularly in comparatively small doses, so as to keep a certain proportion in the person's blood, against the arrival of any possible parasites. This "quinine prophylaxis" — *i.e.*, prevention — is still a useful weapon, but a more evident one is to destroy the mosquito. If the problem were to exterminate all mosquitoes, it would be a well-nigh impracticable one, but Ross was very soon able to show why he had for so long not met with success. He had spent nearly all his time upon kinds of mosquitoes in which the parasite cannot live. Many mosquitoes bite, but the only kinds which can become infected with the parasite producing malaria in man belong to a particular group, of which the general name is *Anopheles* or the Anophelinæ. To exterminate the anophelines is by no means impossible, if we set about it rightly. But the method is all-important; and it applies no less at our own doors than in the tropics.

Photo Elliott & Fry

MAJOR RONALD ROSS

A hundredth part of the labor will have a hundred times more effect if we proceed on sound biological lines. If we want to increase the number of a species, such as our own, we must care for the young, the parents, the homes; if we want to reduce the number of a species, such as flies or mosquitoes, we must attack the young, the parents, the breeding-places. Special inquiry has been made into the habits of anophelines, and we know exactly what the problem is. The male anopheline matters not His mouth parts are not fitted for piercing; he is exclusively a vegetarian. The female alone concerns us, for she alone pierces the skin, and can harbor the parasite. She "breeds in small collections of water — those with a natural earth bottom, such as small pools and patches of water of all descriptions, margins of streams and lakes and odd receptacles coated with humus" — that is to say, with decomposing vegetable matter and soil.

In the first place, then, let mosquito-nets be used; let us dose ourselves with quinine when living in localities where malaria is prevalent; and let us avoid going out into the "dangerous night-air", for it is in that air that the female mosquito flies when she is hungry. But if we attack pools, by whatever means experience has shown to be appropriate in a given case, we shall reduce the number of mosquitoes indefinitely. If we do our

task well enough, all other precautions will be rendered superfluous. And, since no useful method must be ignored, let us observe that the indigenous population of a malarial region harbors the parasite to an extraordinary extent — 80 to 90 per cent — without showing any particular symptoms. These "healthy reservoirs" become the source of infection for anophelines breeding in small collections of water in the neighborhood, and these infected anophelines soon bite any newcomer and infect him

A summary of the means of defense and offense against malaria

The lines of defense and offense against malaria can now be defined; and here they are:

1 Measures to avoid the human reservoirs —
   (a) By means of segregation;
   (b) By screening with nets those suffering from malaria.

2 Measures to avoid the anophelines —
   (a) By choice of suitable locality, when possible;
   (b) Screening houses (windows and verandas);
   (c) Sleeping under mosquito-nets.

3. Measures to exterminate the anophelines —
   (a) Use of the natural enemies of mosquitoes;
   (b) Use of mosquito-killers, such as sulphur and pyrethrum;
   (c) Use of larvicides, kerosene, crude oils of paraffin, etc.
   (d) By drainage and scavenging, to get rid of breeding-places;
   (e) Penalties for harboring larvæ or keeping stagnant water;
   (f) Education.

The substance of modern treatises on malaria prevention cannot be compressed into this chapter, but the foregoing comprise all the measures which, between them, or portions of which, have already abolished the disease in various parts of the world. Here we need specially refer to only a few points of general scientific interest. The first has reference to the natural enemies of the mosquito, and here our Darwinian studies come to our aid. We have seen what the "balance of nature" means, and Darwin has taught us how the numbers of species are kept down by the existence of other species He has also taught us that the immature are by far the easiest victims.

Natural enemies of mosquitoes that should be cultivated

So here, doubtless, the adult mosquito has its enemies, such as birds, but it is the larvæ that perish most abundantly, and their great enemies are fish; or, to put it in another way, the natural food of many fish is the larval form of the mosquito. Thus, in Barbados there are no anophelines and no malaria, though the other West Indian islands are plagued with the disease. Yet Barbados abounds in swamps and ponds. The inhabitants are protected by a tiny fish, so numerous as to be called "millions", a kind of "toy minnows", which live near the surface of the water, and whose staple diet is the larvæ of mosquitoes, if any there be Such fish can be imported into other waters containing mosquito larvæ.

The use of kerosene and other oils is also advocated, for oil forms a film on water, and prevents the larvæ from reaching the surface to breathe. In certain cases this is a useful method, but, as experience has demonstrated repeatedly, the proper method is to drain puddles, swamps and pools, so that they shall not abound in the very midst of towns as still they too often do. Now let us try to summarize results as hitherto attained. In his "Researches on Malaria", Ross eloquently states the facts of the past. Malaria, he says, "strikes down not only the indigenous barbaric population, but, with still greater certainty, the pioneers of civilization — the planter, the trader, the missionary and the soldier. It is therefore the principal and gigantic ally of barbarism. No wild deserts, no savage races, no geographical difficulties, have proved so inimical to civilization as this disease. We may also say that it has withheld an entire continent from humanity — the immense

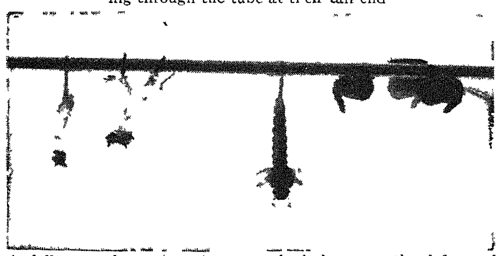
and fertile tracts of Africa; what we call the Dark Continent should be called the Malarious Continent; and for centuries the successive waves of civilization which have flooded and fertilized Europe and America have broken themselves in vain upon its deadly shores." The difference between the races of men living in Africa and in Europe today is probably due to the malaria-bearing mosquito alone.

In Italy the campaign against malaria was started in 1902, and in seven years reduced the annual mortality from about 16,000 to about 4000. In the plain of Marathon, in Greece, thanks to Ross, in two years the proportion of all sickness due to malaria fell from 90 to 2 per cent. And Ross significantly adds, for those who mistake the true spheres of international competition, that "the best kind of international race is that in which nations compete to benefit humanity". Who is trying to win in this kind of "Marathon race"? The Suez Canal Company was cursed with malaria at Ismailia. Italian workmen employed in the construction of the canal probably came as reservoirs of the parasite, and the anophelines did the rest. In 1886 it was computed that every inhabitant suffered from the disease. As early as 1901 the company sought the help of Ross and every breeding-place of the anophelines was abolished Since 1905 *no case of malaria* has been reported in Ismailia; and the company hope to make a sea-bathing resort for the inhabitants of Cairo out of what was a mosquito-plagued town and a nest of malaria.

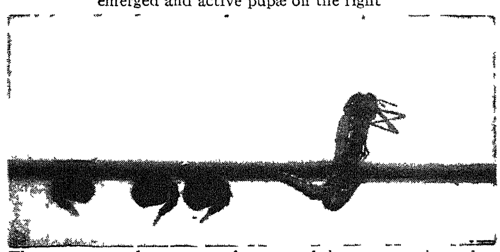
At Port Said, Dr. E. H. Ross, brother of Major Ronald Ross, started successful work in 1906. At Khartoum, Dr. Andrew Balfour began his task in 1904. "He organized anti-mosquito brigades to examine all breeding-places, water receptacles and pools, and then organized measures for drainage, oiling, etc. As the result of five years' work, Khartoum is declared almost mosquito-free, and primary cases of malaria are exceedingly rare." Great success has been attained in Algeria, where the problem of the native Arabs, who act as "healthy reservoirs" of the disease, has to be met.

Sierra Leone, the "White Man's Grave", was the first place chosen by Ross for a practical test of his theory. Magnificent success was attained The African As-

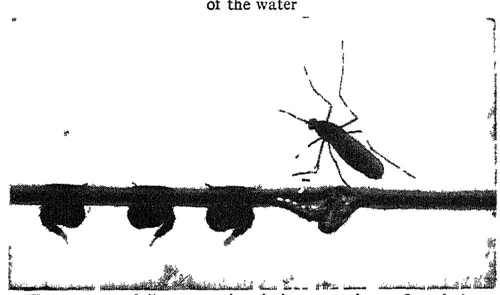
Egg rafts and half-grown larvæ of mosquitoes diving and breathing through the tube at their tail end



A full-grown larva breathing, moulted skins on the left, and emerged and active pupæ on the right



The emergence of a mosquito from one of the pupæ on the surface of the water



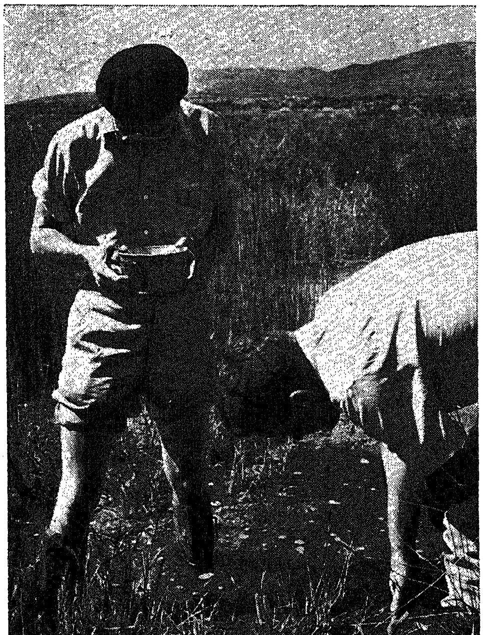
The mosquito fully emerged and about to take its first flight.

STAGNANT WATER THE NURTURE-GROUND OF MOSQUITOES

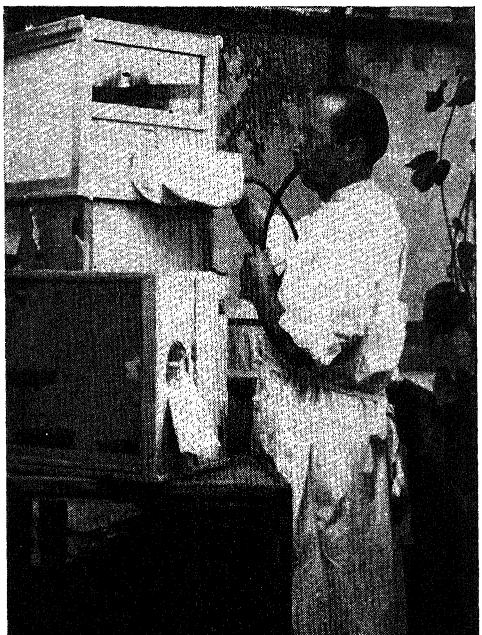
sociation reported that "1908 was the first year in the history of the company in which there had not been a death in the whole of our coast staff".

A WAR TO THE DEATH IN GREECE

Spraying marshes in Greece from the air with DDT and oil, in order to kill the larvae of malaria-bearing mosquitoes. The World Health Organization of the UN took charge of the anti-mosquito war.



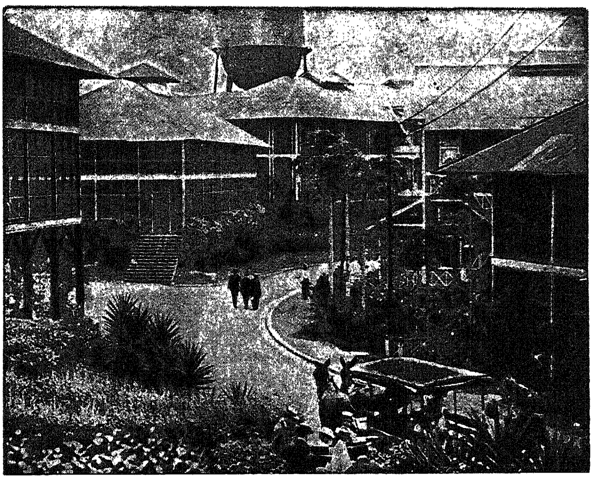
A team of scientists examining the water of a marsh to see if it contains any mosquito larvae.



United Nations

This man is breeding mosquitoes, which are to be used in an extensive series of insecticide tests.

The French tried to build the Panama Canal, and retired, beaten by two kinds of mosquitoes, one spreading yellow fever, the other, malaria, after a loss of fifty thousand men. In 1904 the United States took over the Canal Zone; and the medical men who were assigned the task of clearing up this fever-infested zone set to work, with a staff of two thousand. In 1906 the deaths from malaria were 821; in 1908 they were 282, or 1.34 per thousand, and today yellow fever and malaria have been practically eliminated from the zone. Systematic drainage was the method followed here, together with the use of kerosene in some places, and with the taking of quinine as very subsidiary.



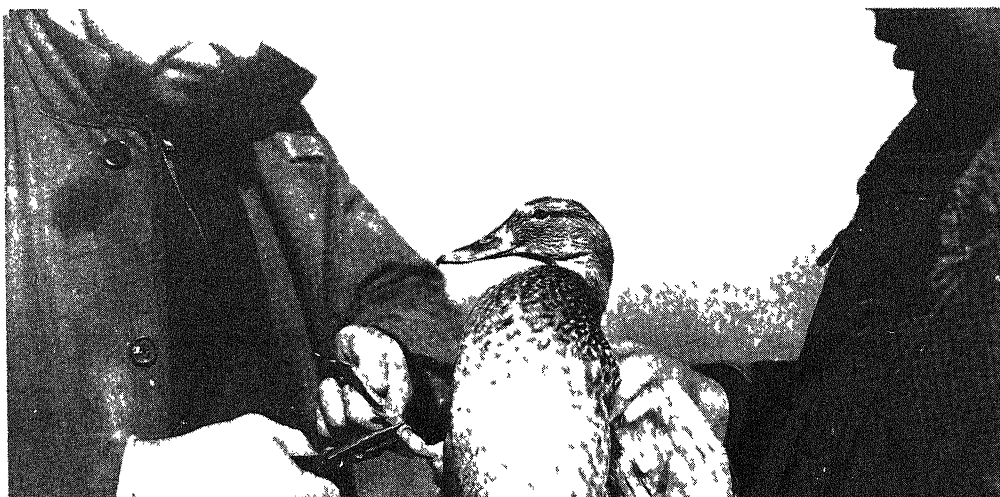
THE MOSQUITO-PROOF QUARTERS OF THE ENGINEERS OF THE PANAMA CANAL

In Colon, Rio de Janeiro, Havana and Belize similar results have been obtained. The West Indies are now making good progress, with the usual quick and unmistakable results. The result of the Spanish-American War was most remarkable, not only in Cuba, as we shall later see in reference to yellow fever, but elsewhere. Just as France failed at Panama because of ignorance — which was certainly no fault of hers, for the mosquito had not then been incriminated — so Spain failed to hold her colonies because of ignorance — in her case largely inexcusable. Ignorance of the laws of health destroyed the health and lives of 100,000 Spanish soldiers in Cuba in three years. The case was similar in the Philippines. Now the unequaled Medical Department of the United States Army is in charge of the health of the Philippines, and everything is changed. The death-rate among the troops in Porto Rico is practically the same as at home, and that of the civil population in Manila compares favorably with the rest of the world.

Nowhere in the world, perhaps, are the ravages of malaria worse than they are in India, where some five millions of deaths are recorded every year from "fever", and the vast bulk of these are none other than malaria. As for the military population, it was recorded in a typical year that, out of a total force of 305,927, there were admitted into hospitals 102,640 cases suffering from malaria. This is not a disease which suddenly and mercifully cuts off its victim, till then healthy, thus leaving room for another healthy man to succeed him. On the contrary, it is a chronic, undermining, slow intoxication; and the net sum of its action within the body is to sap its victim of his energy. Above all, this disease attacks the power to work, the *economic efficiency*, of its victim. Where there are millions of deaths recorded annually, the total of sick is huge — probably seven or ten times as many. In the United States, malaria prevails particularly in the Southern States, where it assumes a very severe form. In our country in the past decade, some years have witnessed the death rate from malaria rise to over four thousand per year. If such be the case in the United States, where a large portion of the country is relatively free from malaria, what must be the conditions in Mexico, Central America and the tropical regions of South America, Africa and Asia, for in regions that are highly malarial at least one-third of the population suffer annually from this dread disease? The problem of malaria in any country is therefore not a matter of humanity only. It is one of national maintenance.

WILDFOWL MIGRANTS ON THE MOVE

These graceful Canada geese are winging their way southward, to avoid the icy blasts of winter.



Both photos, U. S. Fish and Wildlife Service

This female mallard is being banded by a law enforcement officer of the United States Biological Survey; later, it will be released. Bands are used in studying the migratory habits of waterfowl.

BIRD MIGRATION AND HOME LIFE

The Mystery of Their Travels and the
Fascination of Their Home Habits

THE BIRD ON HIS TRAVELS AND AT HOME

FROM the whole field of nature one can select no more engaging study than that of bird migration. The strange calls from the clouds at night, the passage of the well-formed flocks of ducks and geese by day, the flashing of new wings through the garden and the return of familiar voices, inspire us to wonder at the power and precision of the guiding sense that draws birds back each year to their homes of the previous summer. In great waves they come from the South, flood us with beauty and song for a few days, and then pass on. Wave after wave passes over us during April and May until June arrives, when the last immature birds hasten on to their nesting ground and leave us with only our summer birds until the fall migration shall bring them back once more.

A little observation from year to year shows us that the May birds are extremely regular in their appearance and disappearance. One can soon learn just when to expect each species, and if the weather is normal, it will arrive on the day set. The earlier birds such as the robin, bluebird, blackbird, Canada goose, meadowlark and mourning dove, which come during March, are less regular because of the idiosyncrasies of the weather. If there were no such thing as weather and food were always equally abundant, if it were one great level plain from the Amazon to Great Slave Lake, the birds would swing back and forth as regularly as a pendulum and cross a given point at exactly the same time every year. For this migrating instinct is closely associated with the enlargement and reduction of the reproductive organs, a physiological cycle which, under normal conditions, is just as regular as the pulsing of the heart and records time as accurately as a clock. With most species the organs of mature birds begin to enlarge before those of birds hatched the preceding year, and those of the males before those of the females. Because of this, the male birds arrive first and are followed by the females and later by the immature. With some species like the robin, bluebird and phœbe, there is very little difference in the time of arrival, but in the case of the red-winged blackbird, often a period of two weeks or even a month intervenes. This may be a wise provision of nature to insure the selection of a nesting area that will not be overcrowded, for once the male has established himself, and it is often at the same spot year after year, he drives away all other males from the vicinity awaiting the arrival of the females and particularly his mate of the previous year.

But with the later migrants, such as the shore birds, that have a long way to go, the females usually arrive with the males, and with some species courting takes place en route and they arrive at the breeding ground fully mated and ready to nest. The early migrants are those that have spent the winter entirely within the United States. This is true of all the March birds in the Northern States but during the last of the month, the first birds from the West Indies and Mexico begin to arrive in the South. About the middle of April many of the birds that have wintered still further south begin to arrive, including the swallows, the spotted

sandpiper, the black and white warbler and the water-thrush. The last of April and first of May brings even to the Northern States the initial wave of birds from Central America and perhaps even northern South America, and about the middle of this month, when occurs the height of the migration, thousands of tiny warblers, vireos and flycatchers that have been wintering on the slopes of the Andes or the pampas of Brazil are winging their way overhead to Labrador, Hudson Bay and Alaska. The shortest route which one of the very last to arrive, the blackpoll warbler, may travel, is 3500 miles, while those which nest in Alaska must fly over 5000. Some of the shore birds which bring up the close of the migration in late May or early June have undoubtedly come from Chile and even Patagonia and still have several thousand miles to go, so that before they reach their nesting grounds again they will have traveled 16,000 miles since leaving in the autumn.

This constrains us to wonder how these tiny wayfarers are able to traverse such tremendous distances and still return so accurately to their homes. That they do so is certain, for many birds have been marked by aluminum bands placed on their legs so that we know that the same bird often comes back to the same place year after year and builds a nest close to the one of the previous year. Not only has this been proved but it has also been shown that many winter in exactly the same place year after year.

At one time it was thought that they followed well-marked highways in the mountains, rivers and coast lines, surveyed, as it were, by their ancestors and unfailingly followed by all descendants. But now it is believed that these highways are followed only so far as they afford abundant food, and when the food supply lies in some other direction they are regardlessly abandoned. What is it, then, that guides them mile after mile in their flights, flights made mostly under cover of darkness and often at altitudes varying from 2000 to 5000 feet above the earth? A "sense of direction" it is now called, an instinct for recording directions as accurately as a compass, which we, having only so crudely developed in ourselves, are at a loss to understand; an instinct which permits birds to travel north, south, east or west and not lose their bearings. For the migration route of most birds is not directly north and south, and many preface their southerly journeys by long flights directly east or west. The bobolinks and vireos of the Northwest, for example, leave the country by way of Florida or the Gulf Coast and first fly directly east to the Mississippi Valley to join the others before starting southeasterly on their annual 5000-mile August flight to Brazil, whence they return the following May with even greater punctuality to fly over the same fields and alight on the same fence posts. The white-winged scoters which nest about the lakes of central Canada, upon the completion of their nesting duties fly directly east and west to the Atlantic and Pacific, where they winter. Some herons preface their migrations by long flights, even to the north, so that occasionally little blue herons and egrets are found in the Northern States during August and September.

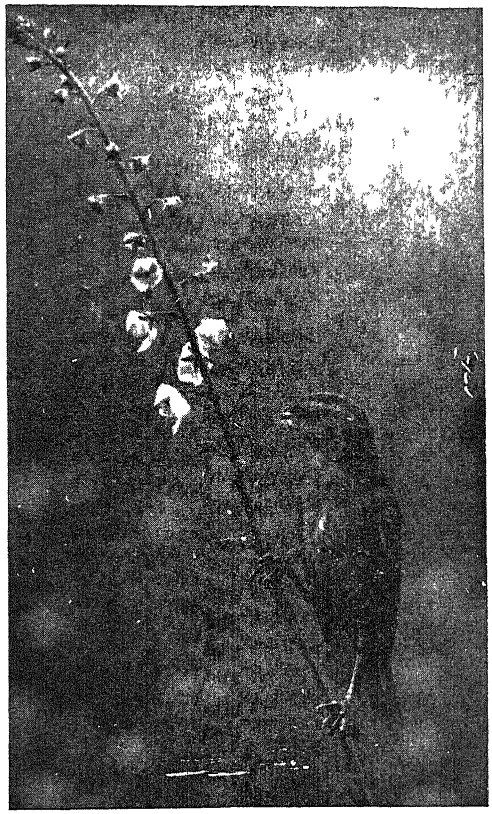
With birds that travel such enormous distances, it is interesting to note their rate of advance. While it is possible for birds to travel great distances without rest, as witnessed by the fall flights of the turnstone from Alaska to Hawaii or that of the golden plover from Labrador to northern South America, distances of over 2000 miles across the open sea, they do not ordinarily progress far in single flights. The spring advance of the robin, for example, averages only 13 miles a day from Louisiana to southern Minnesota. The rate increases gradually to 31 miles a day in southern Canada, 52 miles per day by the time it reaches central Canada and a maximum of 70 miles per day by the time it reaches Alaska. It should not be inferred from this that each robin does not ever migrate less than 13 or more than 70 miles in a single day. Probably they often fly more than a hundred or two hundred miles in a single flight, as do, undoubtedly, many of the smaller birds, but after each flight they dally about their resting

place for several days before starting on again, and this brings down the general rate of advance.

The rate of speed at which birds travel is rather difficult to estimate except for the homing pigeons, which can be timed from one place to another, or the ducks and geese, whose conspicuous flocks traveling high over cities and towns can easily be followed. The championship speed for homing pigeons has been recorded as 55 miles per hour for a period of four hours. A great blue heron has been timed by a motorcyclist keeping directly below it and found to be making 35 miles per hour. A flock of migrating geese has been known to be traveling at a speed of 44.3 miles per hour and a flock of ducks at 47.8 miles. The speed of flight of smaller birds is usually less, although when they mount high in the air and start on their migratory flight they doubtless travel faster than the birds one so often passes flying parallel to a passenger train or suburban car.

The vast majority of birds migrate during the night; some migrate both by day and night, and others only by day. The latter are, for the most part, birds that find their food in the open and can feed as they travel. Such are the robin, the kingbird and the swallows. Other birds, like the sparrows, vireos, warblers and marsh birds, that find their food in the seclusion of trees of dense vegetation, migrate entirely by night. The necessity for this is shown when they arrive at the Gulf of Mexico or other large bodies of water where it is impossible to get food of any kind. If they started early in the morning so as to be across by night, they would not be able to secure much food before starting, and by the time they reached the Mexican side, it would be dark and again impossible to feed. Thus an interval of thirty-six hours would elapse without food, a period that might result disastrously for many birds because of their high rate of metabolism. If, however they spend the day feeding and migrate by night, their crops are full and when they arrive at the other side of the Gulf, it is daylight and they can begin again to glean their living.

During these night migrations birds are attracted by any bright steady light, and every year hundreds and thousands dash themselves to death against lighthouses, high monuments and buildings. While the torch in the Bartholdi Statue of Liberty was kept lighted, as many as 700 birds in a month were picked up at its base. On some of the English lighthouses where bird destruction was formerly enormous, "bird ladders" have been constructed, forming a sort of lattice below the light where the birds can rest instead of fluttering out their lives against the glass. Again in crossing large bodies of water, they are often overtaken by storms and as their plumage becomes water-soaked, they are beaten down to the waves and drowned. Sometimes thousands of birds are killed by a single storm. But of course the vast majority sweep on and arrive at their destinations in safety.



WITH A KEEN SENSE OF DIRECTION
Female bobolink perched on a moth mullein

And so if we step out on a cloudy night when the birds are migrating low to escape flying through the mist-laden clouds and hear their strange calls only faintly resembling their familiar daytime notes, we can picture to ourselves the thousands of winged travelers returning from a sojourn in the tropics and pushing on through the black night, guided by an innate sense of direction, pursuing their course straight to their old homes. We can think over the past ages through which this migrating habit has evolved to the days when all North America basked in a tropical sun and birds darted among the palms and tree ferns without ever a thought of leaving the land of their forefathers. Then we can picture to ourselves the coming of the Ice Age and the destruction of all the life that could not adapt itself to the changed conditions or flee before it. We see the birds gradually pushed to the southward, encroaching upon those already there. We understand the crowding that ensued and how these birds spread northward again as the glaciers receded, only to be forced back once more with the coming winter. Then, with the withdrawal of the ice and the evolution of the seasons, these migrations, by repetition through the ages, became permanent habits or instinct; and with the ensuing modifications in the contour of the continent, and the changes in the location of the food supply, many variations developed in the migration route of each species which seem inexplicable today.

Nest-building and egg laying

In the beginning it might be mentioned that most birds are monogamous, that is, they have the same mates throughout the period of the dependency of the young. With birds the entire cycle from birth to maturity occurs within a comparatively few weeks. The home is built, the eggs are laid, the young are cared for until they become entirely self-supporting, with many birds all within the period of a month or six weeks. With the human species this cycle of events requires anywhere from twenty-one to forty years depending upon the number of children. It is fair, then, to say that birds are monogamous, even though they may change mates from year to year, or even between broods, as is sometimes the case, so long as they do not maintain two mates at the same time. Some birds, particularly those that do not migrate, probably retain the same mates year after year and, even among migratory birds, the same two birds may resort to the same nesting-spot year after year and remate.

We have as yet very little definite information upon this subject, however, and it is one of the problems which "bird-banding" should throw much light upon. In this, as in most aspects of the home life of birds, there is as much individual difference as there is with the human species, which makes it difficult to generalize upon, but most interesting to observe. Indeed the similarity of their actions to ours and their responses to ours are so striking that it has led some nature writers to endow them with an intelligence and power of thought that is not justified by the facts. Some birds are remarkably faithful to one another while others have much greater attachment for the nesting-site than they have for their mates. If one of a pair of Canada geese is killed or permanently separated, the other remains single for years and perhaps never remates. On the other hand, with the majority of birds, if one is killed, a new mate is secured within a few hours.

A few birds, like the pheasants and, probably, most grouse, are regularly polygamous, and others, like the house wren (and probably other species of wrens), red-winged blackbirds, great-tailed grackles and doubtless other species, frequently so; and individual cases can be expected occasionally with almost any species, should there chance to be a preponderance of females, a condition which rarely happens. Polyandry, the mating of one female with more than one male, may likewise occasionally happen, particularly if a stronger male is able to drive away one that is already mated. It is not regularly the case with any bird unless it be the cowbird, and of its domestic relations we still know too little to say definitely.

A few birds are communistic: they build a common nest in which all the females lay eggs and then share the duties of incubation and rearing the young. This is particularly true of the anis of tropical and subtropical America, though many of the African weaver birds and the palm chats of Santo Domingo are communistic to the extent of building a common roof beneath which each pair builds its nest.

After the birds are mated the first thought, of the female at least, is the building of the nest. The male has already selected the general nesting area or territory in which he has been singing and which the female has accepted by accepting him. It is her duty, however, to select the actual site where the nest is to be built and to do most, perhaps all, of the building. With most if not all species of wrens the building of "dummy nests" by the males is a common practice but is apparently rather part of a courtship performance, for they are never used by the female. The male house wren, for example, arriving before the female, proceeds to fill every nesting-box and cranny in the vicinity full of sticks and may even build quite well-shaped nests. When the female arrives and accepts him for a mate, however, she does not at the same time accept the home which he has built; for even though she may decide to use one of the boxes where he has already started a nest, she usually proceeds to throw out all of the sticks which he has laboriously brought in before starting a nest of her own making.

The writer has never known any kind of bird in which the males and females worked equally at nest-building, though with many of the common birds the male makes a pretense at helping. It is his duty to see that no other male or even female of the same species intrudes, and this takes so much of his time that, though he may accompany the female back and forth on her trips, he has little left for gathering material. Judging from the way the female usually treats his occasional offerings, it would seem that his lack of experience has so warped his judgment that he does not know the proper material when he sees it.

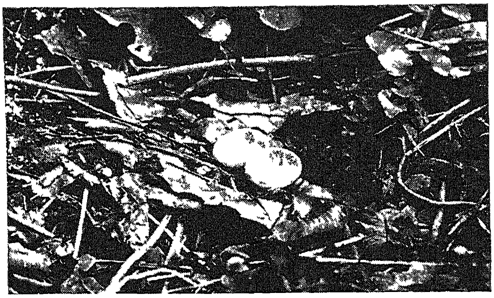
This brings up the question of what determines the proper nesting material for each species. Practically all birds build nests that are characteristic of the species. The materials vary somewhat in different localities depending upon what is most convenient, but, in general, house wrens use twigs, bluebirds use grasses, yellow warblers use cotton, and so on, though often curious substitutes are employed. The writer has, for example, a wren's nest built largely of hair-pins and wire clippings, and a robin's nest in which the customary grasses were replaced by long narrow strips of paper from a near-by paper mill. While the materials with which a bird comes most

SONG IS INDICATION OF NESTING SEASON

This swamp sparrow is announcing his presence to all females of his species and challenging all other males.

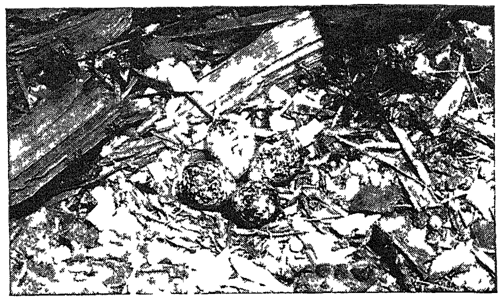
in contact are the ones employed in nest-building, only such materials are used as permit the construction of the type of nest characteristic of the species or family. Baltimore orioles normally weave their nests from vegetable fibers such as the inner bark of milkweed. They will take pieces of yarn or string or horsehair just as readily but never, to my knowledge, will they use sticks, straws or grasses, though grasses are regularly used by the orchard oriole. Marsh birds regularly use dried sedges, rushes or marsh grasses; field birds employ grasses and horsehair; woodland birds use dead leaves, mosses and rootlets, and so on.

THE EVOLUTION OF BIRDS' NESTS



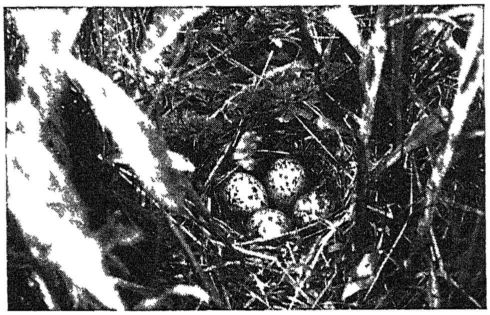
THE SIMPLEST FORM — NO NEST AT ALL!

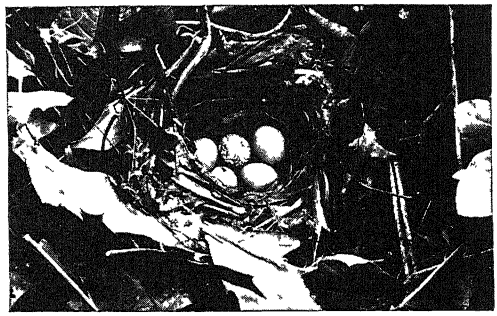
The whip-poor-will simply lays its eggs on the leaves of the forest floor.



THEN, A SLIGHT DEPRESSION IN THE GROUND

The killdeer scoops out a slight depression to hold its eggs





THE DEPRESSION GETS A STRAW LINING AND A PLATFORM OF LEAVES TO RAISE IT FROM THE GROUND

The spotted sandpiper adds a few coarse straws to the depression by way of lining

The speckled egg in this veery's nest is that of the nefarious parasitic cowbird — that knows no home life

A SIMPLE TREE NEST OF STICKS

The platform of sticks built by the green heron

A MORE COMPLICATED TREE NEST

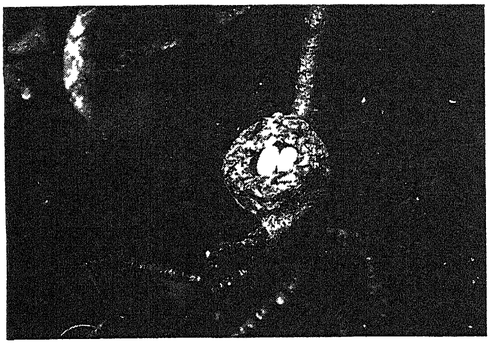
The catbird hollows the platform and adds a lining of rootlets.

A DISTINCT ADVANCE IN COMFORT

The chipping sparrow uses softer grasses and a lining of horse hair. The large egg is that of a cowbird.

THE VERY HEIGHT OF LUXURY

The yellow warbler employs only the softest materials like cotton and hair.



HIGHLY-EVOLVED NEST OF THE HUMMINGBIRD
Decorated with bits of lichens to make it resemble a knot

ONE OF THE HIGH SPOTS IN BIRD ARCHITECTURE
Pendant nest of the yellow-throated vireo

Birds that spend a great deal of time on the wing and come less into contact with nesting materials and nesting-sites show the greatest diversity both as to site and materials. Among our common swallows, for example, the barn and cliff swallows build nests of mud about barns or cliffs; the tree swallows build nests of straws and feathers in holes in trees or bird-houses; the bank swallows build similar nests at the end of holes which they excavate in sandbanks; and the rough-winged swallows utilize old kingfisher burrows or natural crannies about cliffs or bridges or drain-pipes.

The factors that control the selection of the nesting-site are primarily the necessity for concealment, accessibility to the feeding-ground and protection from the elements If birds were capable of worrying over the possibility of the destruction of their homes, their heads would be white before their nests were started As it is, they go about the selection of the site instinctively and finally decide upon one which is usually well concealed from their ordinary enemies such as cats, crows, hawks, owls, jays, grackles, wrens, weasels, skunks, raccoons, squirrels, rats and snakes, as well as being fairly well protected from wind and rain, and accessible to their feeding-ground. The large percentage of nests that are broken up, however, attests the many dangers that beset the bird's home and life. It is no exaggeration to state that less than 10 per cent, perhaps not one in twenty, of the nests which are built each year endure until the young leave of their own accord.

Some species of birds are not adaptable and when conditions change they vanish; others are able to change their natural nesting-sites, make the best of things and even increase. Such are the robin, all the birds that nest in nesting-boxes, the phœbe and the barn and cliff swallows which formerly nested only on cliffs but are now common about our dwellings The chimney swift, which has almost forsaken the hollow trees for the chimneys, is another good example. One often hears of birds nesting in unusual places, like moving street-cars or traveling cranes, under wagons left standing, in clothes-pin bags, in the pockets of scarecrows, etc, but they are always of these adaptable species. It is almost beyond the realm of possibility to have a yellow-breasted chat or a cuckoo or even a catbird behave in such a manner

Before leaving the subject of nesting we ought to try to answer the question, why birds build nests at all. Some we know still lay their eggs on the ground without any nest whatever, and they manage to persist or else we would not have any nighthawks or whip-poor-wills The same is true of many of the sea-birds like the auks and murres At the other extreme are the orioles and the weaver birds, which weave such elaborate nests. Between the two we find all gradations of nest structure from those that merely scoop out a little depression to keep the eggs from rolling, like the killdeer, or those that add a few grasses by way of a lining, like the spotted sandpiper, to those that build rather elaborate domed nests on the ground, like the meadowlark and the ovenbird.

Of the birds that have raised their nests above ground to escape floods or terrestrial enemies, there are some that merely lift them by building a platform of dead leaves, like the veery, or the rails and gallinules in the marsh. Others build crude platforms of sticks in trees or bushes, barely sufficient to keep the eggs from rolling to the ground; such are the nests of the herons, the mourning dove and the cuckoos. Crows and catbirds have advanced a step farther, for while they still use sticks they build deeply hollowed nests and line them with softer materials. Nests of the yellow warbler, redstart and goldfinch, made entirely of soft materials, doubtless represent a still higher stage in the evolution of nests that culminates in the beautifully woven structures of the vireos, orioles and weaver birds. Such is the present status of birds' nests, and doubtless it indicates the various steps through which the more complicated nests have passed.

If we would understand the real origin of nest-building, however, we must go back to the earliest birds when their habits of egg-laying were probably about the same as are those of reptiles today. Turtles bury their eggs in the sand; lizards hide them in holes in stumps or decaying logs; snakes bury theirs in decaying vegetation, and alligators build nests of the same material in which they hide their eggs, and are the only reptiles which are said to take an interest in the welfare of the young later on. But, as in all other reptiles, the eggs are hatched by the heat of the sun or from the decaying material.

Now, it must be remembered that reptiles are "cold-blooded" creatures and are not affected by great changes in their bodily temperature, while the warm-blooded birds and mammals, on the other hand, can endure but a very slight change from the normal temperature of their blood without ill effect. What is true of the grown bird is equally true of the embryo developing within the egg. Its temperature must be maintained or it will not develop and will soon die. There are a few birds, such as the megapodes of the Australian region, which still rely upon the method of burying their eggs in the sand or in piles of decaying vegetation, but they lay their eggs at a time when the temperature is remarkably uniform in the places which they select. All other birds have to depend upon supplying the heat from their own bodies; that is, they have to incubate their eggs, and it is the need for incubating the eggs that gave rise to the nest-building habit. Birds that were in the habit of nesting in holes in banks or in trees, where they could remain with their eggs with no great inconvenience, did not have to learn how to build nests, except in so far as they had to learn to dig their own excavations instead of accepting natural cavities. Such is the habit of the woodpeckers and the kingfishers today. They excavate their nesting cavities, but they build no nests within for their eggs. Birds that had been in the habit of burying their eggs, however, and now had to lay them on the surface of the ground where they could be incubated, had other problems to meet. There were the floods, the cold, wet ground, the numerous terrestrial enemies, all threatening to destroy the eggs. It is easy to imagine, therefore, that those individuals that learned to raise their nests away from the ground were the ones that persisted until the habit was formed. The first nests were doubtless very crude and the beautiful structures with which we are familiar are therefore the result of a gradual evolution such as that already indicated.

We have stated that nests are ordinarily built by the female birds though the male often makes a pretense at helping. The time required depends a good deal upon the time at the disposal of the birds, but, with ordinary birds, like robins, or blackbirds, it is about six days. Three days are spent on the outside and a like time on the interior. The same bird, however, if the first nest is destroyed while the eggs are being laid, might build an entirely new nest in a single day. A pair of phœbes, on the other hand, under observation, began repairing an old nest fully a month before any eggs were laid. Usually the nest is completed the day before the first egg is laid.

Incubation does not ordinarily begin until egg-laying is completed, so that all of the eggs will hatch at about the same time. Otherwise the first young to hatch would have an unfair advantage over the others in the nest. Occasionally one finds owls or bitterns beginning to incubate before all of the eggs have been laid, but they are, perhaps, less regular about egg-laying than most birds. Most birds lay one egg each day at about the same time, but larger birds, like hawks, owls, and geese, have intervals of two days.

As the time for incubation approaches, the bare area on the middle of the breast becomes suffused with blood and is termed the "blood spot", and the bird becomes "broody". Ducks and geese which have practically no bare area on the breast then proceed to pull out the down from that region so as to bring the eggs in direct contact with the skin. Incidentally, this down forms a blanket with which the eggs are always covered when the duck leaves them to feed.

When both birds are colored alike, they usually share equally the duties of incubation, but when the male is brighter than the female, he is not often seen on the nest, the rose-breasted grosbeak being an exception. Ordinarily, he either stands guard on the edge of the nest until the female returns from her feeding excursions or else brings food to her. Sometimes he feeds her on the nest, but more often he calls, as he approaches, and she flies out to meet him. The easiest way to find a marsh hawk's nest is to listen for the returning male and then note from what spot the female flies up to meet him and takes the food from his claws. The care of the female by the male is carried to the extreme by the African hornbills, in which species the male walls up the opening to the nest in a hollow tree with mud until only the female's bill can be protruded. He then proceeds to bring her all her food and likewise that for the young later on, for she remains imprisoned until the young are nearly full grown. So great is the task of providing food for the whole family, we are told, that he becomes very thin and often succumbs during severe weather.

In a few birds the males do most or all of the incubating and care of the young. This is said to be true of the emus and cassowaries of the East Indies, the rheas and tinamous of South America, of ostriches, at least in captivity, and more particularly of our own phalaropes. In the case of the phalaropes the males not only do all of the domestic chores but they are likewise less brightly marked than the females, apparently a complete reversal of the sexes.

The period of incubation depends largely on the size of the egg and the nature of the young, — larger eggs, those from which precocial young hatch, requiring longer

A DUTIFUL HUSBAND

It is the exception for a brightly colored male bird to assist in incubating, but the rose-breasted grosbeak is here shown relieving his spouse, as he should

periods. The actual time varies from 10 days in the cowbird to from 50 to 60 in the ostrich, or even from 70 to 80 in the case of the emu. Sparrows require from 12 to 13; thrushes, 13 to 14; hens, 21; ducks, from 21 to 30, depending largely on the size; geese, 30 to 35, etc. An apparent exception is the hummingbird, which requires from 14 to 15 days but has the smallest egg of all. This may be due to the fact that she receives no help whatever from the male, and the eggs may become unduly cooled during her feeding excursions, for it is known that unusual cooling of the eggs delays the hatching if it does not entirely prevent it.

The extremely short period of the cowbird is perhaps an adaptation to its parasitic habits, for if the young cowbird hatches ahead of its foster brothers it has a better chance of getting most of the food and either starving them to death or ousting them from the nest.

Young birds are assisted in getting out of the shell by what is called the "egg-tooth," a hard calcareous tubercle on the upper mandible which is used as the cutting tool in "pecking" the egg. The bills of all embryo birds are very soft, making such an instrument necessary. This egg-tooth persists for several days after hatching and is quite conspicuous on some birds. Many birds, particularly grouse and quail, cut a neat little cap out of the larger end of the egg with this egg-tooth, but others break the shell irregularly. Most birds are very careful to remove the empty shells from the nests, either swallowing them or carrying them off some distance. Birds that have precocial young, however, that do not stay in the nest for any time after hatching, do not bother with the empty shells.

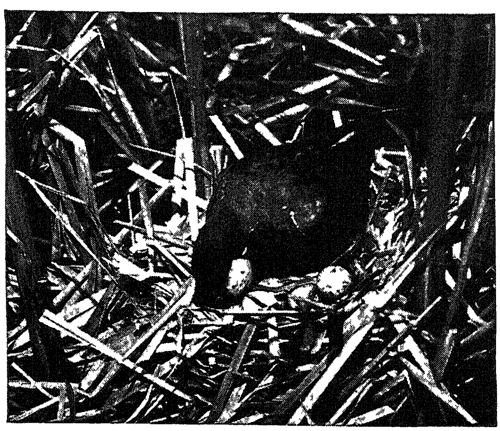
During the period of incubation the eggs have to be turned once or twice a day so that they will be heated evenly and so that the membranes will not adhere to the shell and prevent the free passage of air to the interior. Some birds turn the eggs with their feet and others with their bills, and usually it is at the time that the female returns from a feeding excursion.

The young birds, their growth and care

Young birds at hatching are of two general types. They are either precocial or altricial. Precocial young resemble chickens in that they are wide awake when hatched, are covered with down, and are able very soon after drying off to follow their parents in search for food, a large part of which they find by themselves. Altricial young, on the other hand, are almost naked when hatched, their eyes are not yet open, and they are cared for in the nest by their parents for periods varying from a week or ten days with terrestrial sparrows, to nearly a year with the condor and the wandering albatross.

In general, terrestrial, diving and swimming birds have precocial young, while arboreal birds and birds that search their food on the wing have altricial young. Among the former are the loons and grebes, the ducks, geese and swans, the shore birds, the marsh-birds and the fowl-like birds. Some young, such as those of the gulls and terns, remain in the nest or, at least, have food brought to them for weeks, but in other respects are entirely precocial, being wide awake, covered with down, and able to run about shortly after hatching. Other young, such as those of hawks, owls, nighthawks and whip-poor-wills, and even herons, are covered with thick down when hatched but in other respects are altricial, being blind at first and quite unable to help themselves for a long time.

FLORIDA GALLINULE INCUBATING
Incubation is the prime requisite in the care of the eggs.



ONE GOOD TURN DESERVES ANOTHER
The eggs have to be turned occasionally during incubation

PRECOCIAL YOUNG OF THE RUFFED GROUSE
Covered with down, wideawake, and able to run soon after hatching

ALTRICIAL YOUNG OF THE COMMON CROW
Born blind, naked and helpless A contrast to the day-old youngster on the left

At the opposite extreme among altricial young are those of the flicker, the kingfisher and the hummingbirds, which are naked. The majority of woodpeckers have a few hair-like feathers when hatched, and cuckoos have them quite thread-like. Young cuckoos and kingfishers are worthy of attention again when they come to attain their first real feathers, for, unlike most birds, they remain in the sheath until nearly full grown. For a time the young birds seem covered with tiny lead pencils and the transformation to the fluffy feathers, by the breaking open of the sheaths, is very rapid, requiring but a few hours. With other young birds, the transformation from almost naked babes into fluffy feathered creatures is gradual. Whatever down there is, is pushed out on the tips of the incoming juvenile feathers, which begin to break their sheaths before they are quarter grown. In the case of a red-winged blackbird, for example, the "pin feathers" have pushed the down entirely out and are well grown by the end of the fifth day, and on the sixth the sheaths of the "pin feathers" have begun to break. Three days later the feathers have unfolded sufficiently to hide most of the bare spots, and by the eleventh day the young bird is apparently fully feathered except around the eye, which area, in blackbirds, is the last to be clothed. Of course, the feathers continue to grow after the eleventh day, but the young bird has left the nest and is already able to fly short distances. The change, however, has been gradual, requiring several days, while in cuckoos and kingfishers it seems to occur within a few hours after the sheaths break open.

When the young hatch they are not fed immediately, the time elapsing before the first feeding varying with different species. The method of feeding likewise varies. Many birds are fed by regurgitation. The parent bird swallows the food and gives it to the young in a partially digested state. Some, like the mourning doves and goldfinches, continue this process as long as they feed the young. Herons and bitterns do also, at least as long as the young are in the nest, and one never sees one of these birds returning to its nest with anything in its bill. Waxwings use their crops as regular market baskets and return to the nest with their necks bulging with a great variety of small fruits and insects mostly in a good state of preservation. With the majority of common birds, however, this method of feeding is continued but a short time, if at all, and it is a familiar sight to see the parent birds returning to their young with insects or fruit in their bills.

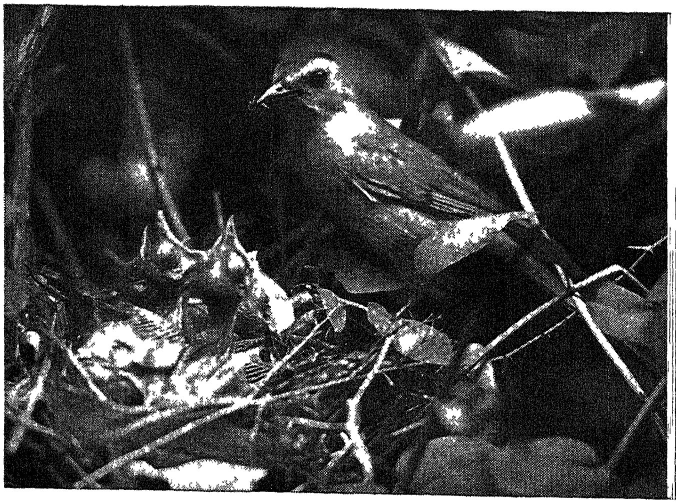
The commonest method of feeding is the placing of the old bird's bill containing the food far down into the throat of the young. This prevents any live insect from escaping. In birds that regurgitate food, however, there are several different ways of transferring the food. In birds like the pelicans and cormorants, which bring back fish in their throat pouches, the old bird merely opens its bill and permits the young to rummage around inside. Sometimes they almost disappear down the throat of the old bird. With the herons, the old bird turns its head on the side, and the young grasps it, near the base of the bill, with a scissor-like ac-

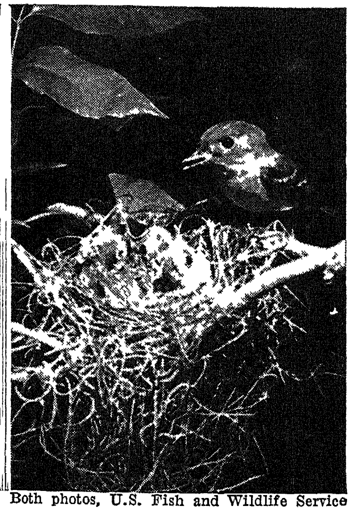
tion, dilating its lower mandibles (lower jaw) so as to catch whatever comes out of the throat of the adult bird. To the onlooker, it appears like a very clumsy performance, but little food seems ever to be wasted by spilling. Young mourning doves have swellings at the corner of the mouth, which the old birds press when they interlock bills to inspire the proper swallowing action in the young. I once tried to raise a crippled young dove and could not get it to swallow anything, even that which was forcibly put into its throat, until I discovered the nervous adjustment between the swellings and the throat muscles. After that it was easy, for I merely had to touch the swellings, and it was like pressing a button. The little bird's mouth opened, and the throat muscles commenced to work even before the food entered the bird's mouth.

With all birds there is a nervous adjustment that prevents overfeeding. Birds do not feed their young in rotation, as one might naturally expect. Ordinarily they feed the hungriest one first and continue to feed it until some other one gets hungrier and stretches its neck further and cries louder. This might result in overfeeding the largest young one, but, fortunately, when the young bird has had enough, its throat muscles no longer function.

After each feeding, the adult bird looks down into the throat of the young one (the young bird, if well, keeps its mouth open for food as long as the adult is about), and if the last morsel is not promptly swallowed, the parent takes it out again and gives it to one of the other young. It is this habit of feeding the one with the longest neck and widest mouth first that causes fatalities among the rightful young in a nest that holds a young cowbird. The cowbird has a long neck and wide mouth.

After the young have left the nest the parent birds are not as particular about putting the food far down the throat of the young, for the young bird soon has to catch insects or find food for itself. It is interesting to watch a family of young swallows learning to catch insects on the wing. As long as they are in the nest, they are fed like other young, having the food placed far down their throats, but once they leave the nest, such procedure ceases. It is but a short time before the old bird merely sweeps by the young one and drops the food into the open mouth without stopping; and when the youngsters are able to fly, the same operation is employed in full flight. It is as though the old birds were teaching the young to catch things out of the air. Young duck hawks can learn in much the same way to





Both photos, U.S. Fish and Wildlife Service

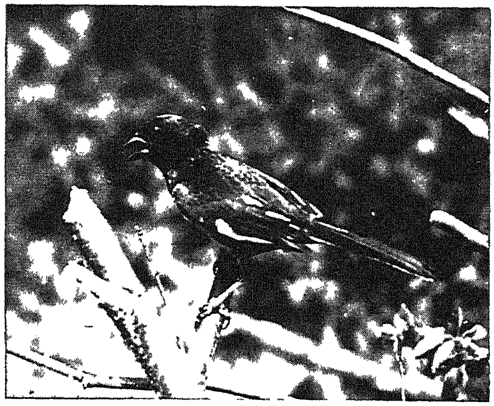
Nesting in bush honeysuckle, the parent catbird carries home a caterpillar to its hungry family. The young are five to six days old.

The adult Acadian flycatcher and young at its nest in a swamp ash.

pounce on birds in full flight. When the young are able to fly, the old birds merely swing by the nesting ledge with the food in their talons and the young ones fly out, turn over beneath the old bird and strike at the food as though it were being carried along on its own wings.

The amount of food which birds, especially insectivorous species, require, is always a surprise to one observing it for the first time. The classical experiment of feeding a young robin all the earthworms it can eat at the time it leaves the nest can scarcely be improved upon. The result with the original robin experimented with was fourteen feet of earthworm in one day. Experiments with young crows have shown that they require at least half their own weight of food each day merely to exist and that they can easily consume food equivalent to their full weight each day. Many young crows that are kept in captivity, as well as other young birds, are starved to death because their owners do not realize how much food is required. They do not eat very much at a time but their digestion is so rapid that their parents feed them almost continuously from daylight until dark, and, as Mr. Forbush says, they eat the equivalent of at least eight full meals each day. If one wished to be duly impressed by the amount of food required by a young bird, he should put up an observation blind by a nest of young birds of almost any species. Quite naturally they do not require as much food when newly hatched as when they are ready to leave the nest. Birds that feed by regurgitation and those which bring back large pieces of food naturally do not feed as often as those which make the trips to the nest with only their bills full. Hawks usually feed only about once an hour; hummingbirds, once in twenty minutes, but a pair of chickadees that I watched at their nest last summer made 35 trips to the nest in thirty minutes. A pair of rose-breasted grosbeaks are recorded as feeding their young 426 times in 11 hours, and a house wren, 1217 times in the 15 hours and 45 minutes of daylight.

Young birds, until they have developed a covering of feathers, require frequent brooding by the old bird to keep them from getting cold and likewise to keep them from getting too hot if the nest is exposed to the sun. Altricial young are never brooded after they leave the nest, but precocial young are brooded for five or six weeks (or until they grow their juvenile feathers), wherever it strikes the fancy of the old bird, though seldom in the nest which they have left. A pair of Canada geese, however, that I had in captivity, took their goslings each night back to the old nest to be brooded, though it was not much more than a depression in the ground. Florida gallinules, and doubtless other marsh-birds, as well, often make new nests or rafts of rushes on which to brood their young. Wood ducks, grebes and swans



MALE TOWHEE SCOLDING

often take their young on their backs and brood them beneath their wings. Indeed, the grebes often take this method of conveying their young to safety, closing their wings down tight upon them and diving with them. The European woodcock, on the other hand, is said to convey its young to suitable feeding spots between its thighs, flying with dangling legs, and it is apparently a common practice with rails to seize their young by any convenient appendage and rush them to safety.

The varying degrees of attachment for their young which birds show, and their methods of expressing it, are always interesting to observe. Few birds seem to feel much of a parental instinct when the young are freshly hatched. The instinct increases daily, and reaches a maximum

at the time when the young are ready to leave the nest. The same is true of the bird's instinct to incubate. When the eggs are freshly laid the bird will desert them readily, but at the time when they are hatching, even the most timid birds will cling to the nest in the presence of danger. Bird photographers should always bear this in mind and never try to photograph birds at their nests when they are just beginning to incubate or just beginning to brood. Most hawks, herons, cormorants, pelicans, yellow-breasted chats and

CANADA GEESE DEFENDING THEIR NEST
The goose covers the eggs while the gander engages in active combat with the intruder (birds nesting in captivity)

mourning doves have their parental instincts very poorly developed, and readily desert their eggs or young in the presence of danger. Most chickadees, and a great many warblers and vireos, on the other hand, have their parental instincts so highly developed that they pay no attention to dangers while they are incubating or brooding. At least they will permit a very close approach, and even let one stroke them while they cling to the nest. Between the two extremes there are all gradations, no two birds behaving exactly alike in the defense of their nests or young.

Many birds feign being wounded in an attempt to lure one away from the nest, and drag themselves pitifully over the ground in the hope that the enemy will follow them and lose track of the nest or young. Other birds dart at one's head and attempt to inflict blows with their bills, their wings or their talons, while the majority merely express their distress by loud calls which attract all the other birds to the vicinity.

It is interesting to observe the varying times at which fear first develops in the young birds. It is apparently instilled into them by their parents, because when eggs from wild birds are hatched under domestic birds the young seem never to develop the sense of fear for human beings. There are some exceptions to this statement, however, especially among precocial birds, many of which are extremely timid even when hatched under most quiet hens and lose their fear very gradually. In the wild state, precocial young seem to respond to this fear instinct as soon as they have dried off and are able to run. With altricial young, on the other hand, it is not until they are developing their feathers, a few days prior to leaving the nest, that they crouch and try to hide at one's approach. Before that time, they stretch up their necks and open their mouths for food just as freely for a human being as for their parents.

It is about the same time that the young birds apparently come for the first time to the realization of the meaning of the different calls of their parents and crouch for one note, stretch up their necks at another, or remain passive for a third. Anyone familiar with poultry knows of the various calls of the old hen to her chicks. Her vocabulary is not extensive, but no one would deny the fact that she has a method of conveying many different instructions to her chicks. They all crouch when she cries hawk, they scatter when she cries cat, and they rush to her when she cries food, etc. Other birds are just the same, but it takes a discerning ear to catch the differences in notes, and it is impossible to put them in print. Distress calls are usually recognized by all species of birds, and they fly to the scene of trouble.

Whether the other notes are understood by all species or whether each species has its private language, we have no very good way of knowing. It is a study that will take a refinement of observation that we have not yet attained.

It is said that the call notes of a bird are instinctive and that its song is learned by imitation, but the latter statement has not been entirely proved. Certainly a crow will caw and a duck will quack whether or not it ever hears any others of its kind, and I am inclined to believe a robin would sing like a robin if it never heard another bird sing. But when young birds are raised by other species, never hear their own kind and continually hear the songs of their foster parents, they do seem to acquire songs resembling more those of their foster parents than their own. We should remember, however, that the power of imitation is quite general among birds and not confined to the mockingbirds alone, though with them it reached its greatest perfection. The only fair test would be to raise a young bird to the singing age without its hearing any other song. So far as I know, this has never been done.

All young birds by the time they leave the nest have well-developed distress calls and food calls. Some young like the Baltimore orioles and the Florida gallinules never stop calling except when notified by their parents that danger is near. Other young call when they are hungry or think they are lost, and thus, though the brood may be quite scattered, the parents are able to keep track of them. Many persons, finding a young bird without its parents, think it has been deserted and feel that they must take it home and feed it. This is a mistaken kindness for, usually, it merely signifies that the brood is somewhat scattered, and that the parents are busy feeding the other young; particularly is this so if the young bird is quiet, for that indicates that he has just been fed and that the old birds may not be back for some time. If the young bird is put up out of reach of cats, the parents will sooner or later find it and care for it, for its food call will carry as far as it could possibly fly since its previous feeding.

The syrinx of a young bird, and therefore its song, does not fully develop ordinarily until the winter or following spring, though I believe there are instances of domesticated song birds singing the same year they are hatched. It is not the case with wild birds, however, though some of the shaky voices that we hear in the fall may possibly be from early hatched birds.

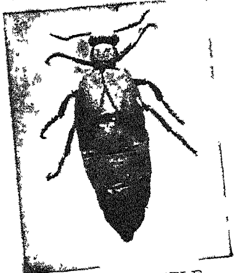
The time required for the young bird to acquire its full plumage varies with different species. Ordinarily, by the time the wing feathers are full grown the body feathers of the juvenile plumage begin to drop out and the first feathers come in. If the male and female are alike, this plumage, which is usually fully acquired by September, will be almost indistinguishable from that of the adults, but,

LEAVE IT ALONE

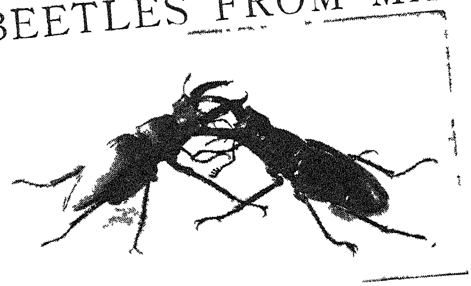
It is a mistaken kindness to carry a young bird home and try to feed it under the impression that it is lost. Its calls for food will ordinarily bring its parents. This is a young yellow-breasted chat, not calling because it has just been fed.

in brightly colored birds of species in which the male and female are different, it will resemble the female or the male in winter plumage. The next spring it will have a complete or a partial molt of its body feathers to bring it into its breeding dress just as in the adult. Immature scarlet tanagers and goldfinches and indigo birds then closely resemble the adults, being only slightly less brilliant. With some of the warblers, however, like the redstart and myrtle warbler, there is but a slight molt and the immature male still resembles the female with a few of the male feathers. This often results in the recording of female birds singing. Some birds seem to require even more than the two years to acquire the full brilliancy of plumage, but ordinarily after the second year the health of the bird more than its age will affect its plumage.

TYPICAL BEETLES FROM MANY LANDS

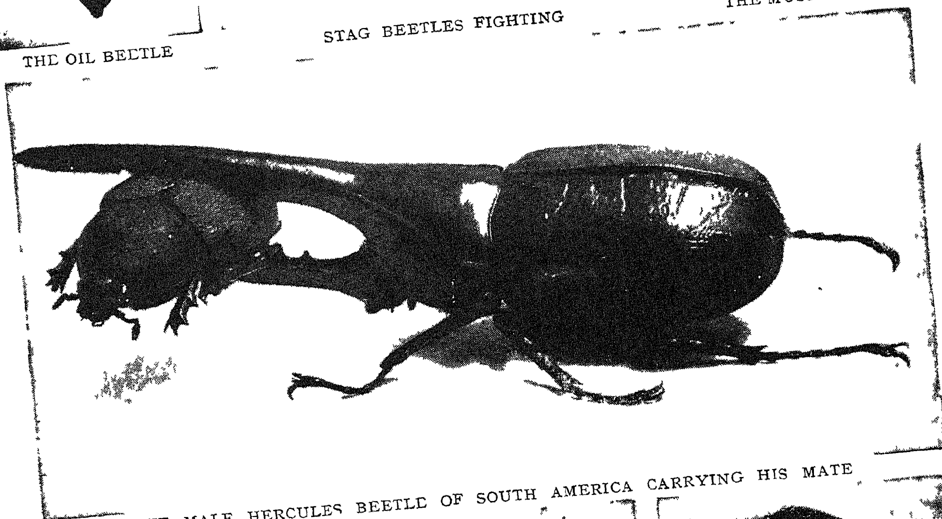


THE OIL BEETLE



STAG BEETLES FIGHTING

THE MUSK BEETLE

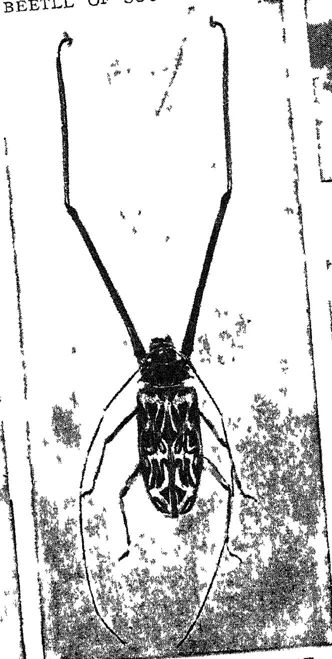


THE MALE HERCULES BEETLE OF SOUTH AMERICA CARRYING HIS MATE

THE ROSE BEETLE

THE DOR BEETLE

THE MEXICAN POLYPHYLLA



THE HARLEQUIN BEETLE

THE GOLIATH BEETLE

INSECT AGAINST INSECT

The Vast Importance to Human Prosperity of the Most Trifling Things of Nature

ORGANIZING THE BATTLE OF THE FLIES

THE time will come when the herd-books of the cattle-breeder, the records of the flock-master and the stud-book of the horse-breeder will cease to be the sole official documents of the agriculturist. The day of the entomologist is at hand. He will protect our fields and orchards, our forests and plantations, as the police department now protects our streets. We spend great sums in experimental agricultural stations, upon testing the relative values of fertilizers, upon creating new varieties of food growths, upon calling into existence new species of plant and flower and vegetable. We develop new varieties with great efficiency, but we do not effectively protect those which we develop. In days to come the entomologist will be of as great importance to the community as the agricultural experimentalist of our generation has been.

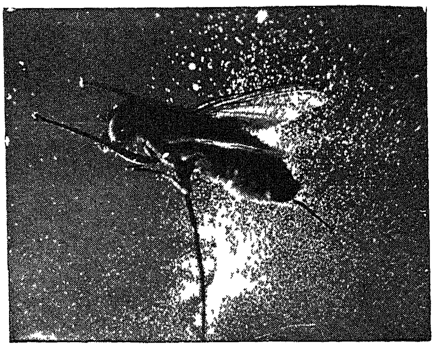
He will deal with insects as Luther Burbank deals with flowers, fruits and vegetables. He may not develop new varieties; though, with the example of the poultry-breeder and master of flocks and herds before him, even this is not impossible. But undoubtedly he should be able to encourage the increase of beneficial insects, and to lessen the ravages of those that are harmful. If ants can nurture aphides, surely man can stimulate the multiplication of ichneumons, which destroy the ravaging aphides. The work has been begun in the United States, where nearly every state has its state entomologist, in addition to experts employed by the federal government. In California they conserve and treasure the ladybird; and a farmer whose crops are infested with insects which form the food of these beneficent bugs calls at headquarters for a supply of ladybirds, just as in case of our own illness a doctor calls for a supply of vaccine or diphtheria serum

We have "tamed" the silkworm moth, we have improved and almost domesticated the bee, we cultivate bacteria as freely as mustard and water-cress, we have farms for butterflies and moths. It remains to be seen whether the ingenuity of the scientist is sufficient to enable him to collect breeding supplies of ichneumons which will attack the plant-lice, the destructive lepidoptera, the loathsome cockroach and the larvæ of other harmful or offensive pests; the fungoid parasite which is fatal to the house-fly; and the many other known parasites friendly to man in so far as they are destructive of his enemies.

Entomology is still in its infancy; those devoted to it are regarded by the multitude as harmless eccentrics, as butterfly-chasers and pond-scavengers. The simple fact is that, limited as is their scope, the entomologists of the present-day world wield powers of almost incomparable importance. There is a parasite for almost every vegetable growth employed in manufacture or for food. The cotton industry in this country is at the mercy of various parasites of the cotton plant, particularly of the boll weevil. The West Indies maintain their prosperity only so long as they can keep in check the ravages of the banana parasite. Our leather dealers face panic prices in the event of a pest of warble-flies, which lay their eggs in the hide of the living cattle. The breeding of do-

mestic animals is impossible in a great part of Africa until entomologists can set a parasite to catch a fly. A mosquito for half a century prevented the building of the Panama Canal. Fruit, wheat, potatoes and every kind of garden produce are menaced year by year by their several parasites; and though the man in the street hears nothing of it, skilled scientists are constantly at work, winter and summer warring upon the pests which do the damage. We find evidence of their labors in unexpected quarters: one has but to glance at the restrictions upon the importation of plant life into the United States, to see how thoroughly the question has been officially explored.

Yet, in spite of all precautions, pests do spread. America sends them to Europe, and Europe sends hers to America. A pinch of eggs of the gypsy moth, which was an alien to the United States, resulted in such a crop of moths of that species as to cause America more loss in the course of years than any war in which she has ever been engaged. Upon the testimony of our government experts, America still loses over a billion dollars every year through the damage done by insect life to our farm and garden crops.


A HOUSE-FLY KILLED BY FUNGUS

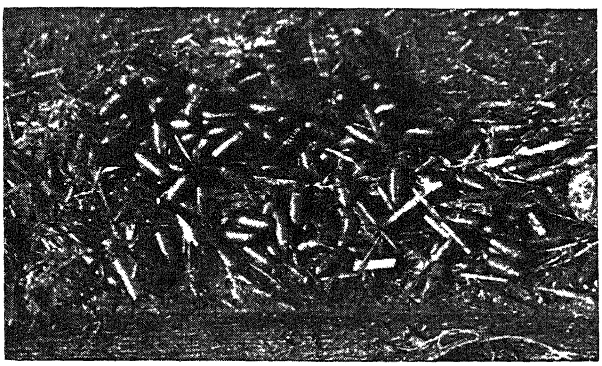
Insect enemies are always at work. They destroy our forests, as they destroy the forests of other lands and rob us of our fruit. The government finds it worth while to have entomological experts constantly on the move throughout the country, observing, learning, teaching and distributing information concerning the affairs of our agriculturists and their insect enemies.

Three examples come to mind of the way in which the entomologist goes to work for the benefit of his fellows. A shrewd and prosperous farmer noted that during one midsummer his fruit-trees were as bare of foliage as they had been in midwinter.

"Blight", was his comment. "Grubs", declared his son. "Rubbish!" retorted the father. The son, however, backed his theory in the autumn by plastering certain tree-trunks with treacle; and it was found that trees so treated bore good crops in the following year, while those not so protected failed as before. Closer observation followed, and in the treacle were found certain insects, which were sent to an entomologist. The son was right. The insects caught by the treacle were the wingless females of the destructive canker-worm, which, completing their metamorphosis in the ground, must crawl up the tree. The males fly, of course. Now, the crawling female deposits her eggs in the branches of the tree, where the caterpillars are hatched, to devour every green thing within reach. "Grease-band your trees, and the females cannot climb them, so your fruit will be saved," was the official advice. It was followed, and the farmer's orchards today are a picture of prosperity.

A second instance comes from South Dakota, where, owing to the enormous multiplication of bark-beetles, the destruction of pine-trees was reckoned at not less than a thousand million cubic feet of timber. At the beginning of an invasion the beetles attack only decaying or fallen trees, but when favorable conditions give the insects a good start, they gain energy, and become a veritable plague among the forest giants. All manner of devices were tried to check the invasion without effect. Trees were peeled, to expose the galleries of the larvæ; efforts to cut the affected timber were equally ineffectual. Suddenly there appeared a curious fungus upon the trees, which proved fatal to the beetles and their larvæ. Man had not brought it there, but he observed its advent and effect, and forthwith was able artificially to increase its distributional range, and save his timber from the beetle.

The third instance is furnished by the California State Commissioners of Agriculture, who long sought to stay the ravages of the codling moth It is this moth which lays eggs in the blossom of the apple-tree, so that the grub becomes parasitic upon the apple itself, undergoing its metamorphosis within the living fruit, and eventually tunneling its way out to complete its life cycle. An apple thus affected is not only disfigured, but never attains maturity. The least puff of wind suffices to dislodge it, and enormous quantities of spoiled fruit — "windfalls" — result. The California Commissioners assert that they have discovered the special parasite of the codling It is an ichneumon, known as *Ephialtes carbonarius*, and attacks only this one species. By means of its long ovipositor drill it deposits its eggs within the body of the caterpillar In that body the egg is hatched — or it may be a number of eggs; the larvæ feed upon the tissues of the living host which it eventually kills, undergo all their changes within its body, and, after the chrysalis stage, emerge as fully developed flies, ready to carry on the good work for the protection of men's orchards. The discovery was no sooner made than the state authorities set to work to protect and encourage the development of this ichneumon; and five or six years ago they were hopeful that they would succeed in practically exterminating the codling moth from the fruit-farms of California.


PUPÆ OF THE HOUSE-FLY, BLUEBOTTLE, AND OTHER DISEASE-SPREADING FLIES UPON A MANURE HEAP

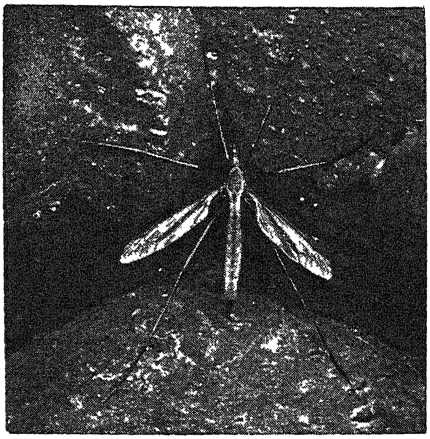
These ichneumons are truly marvelous allies of man. They number thousands of species, and assume an infinite variety of forms. Some are quite large, wasp-like creatures, but, unlike the wasp, they never hum; they approach with noiseless wings, as by stealth, to plunge their ovipositors into the body of the victim with as little demonstration as possible. Ichneumon will kill ichneumon, for some of the larger members of the clan treat the smaller species as the latter treat other insects.

We may thank the Microgaster for the preservation of our cabbage gardens, for it is this form which assails the teeming larvæ of the cabbage butterfly Our roses are saved for us by the Aphidus, another form, which selects the hated greenfly for its cradle and larder in one. The pine forests of Europe are policed by the *Exenterus marginatorius*, which preys in the manner indicated upon destructive pine saw-flies. The voracious caterpillars of the hawk-moths are prevented from running their destructive course by species of the Banchus genus The life-histories of a vast number of the ichneumons have been worked out We find their eggs, as we have seen, within the living bodies of other insect larvæ — as many as a thousand in the body of a single caterpillar; we find the insects marvelously locating larvæ hidden in the trunks of trees; they even have the audacity to plant their eggs within the eggs of other creatures — of spiders and beetles, for example.

Of flies which begin their lives within the eggs of other insects, the fairy-flies are the most fascinating little examples. There are about 185 species, each species has its own particular host-egg, and fifty-nine fairy-flies have been known to emerge from one egg of a beetle. Some of the adult flies are so small that they can walk five abreast through a hole in a card pierced by a pin. Of course, there are beetles and beetles, some of which we would not willingly surrender even to the wonderful little fairy-fly; but there is one misnamed "beetle", the cockroach, that

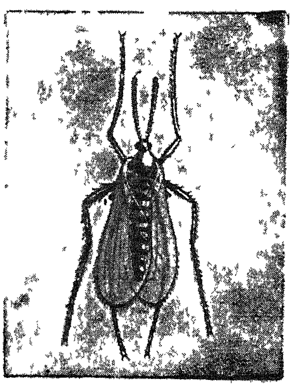
we should all be glad to make over to the javelin wasp, which is known to deposit its own eggs within the singular egg-capsule of this despised house-pest.

Not every insect which possesses an ovipositor drill is an ichneumon, of course. We find instruments of this description possessed by the gall-wasps or gall-flies. Exactly how they produce the curious galls, upon oak and rose and so forth, we do not at present know.

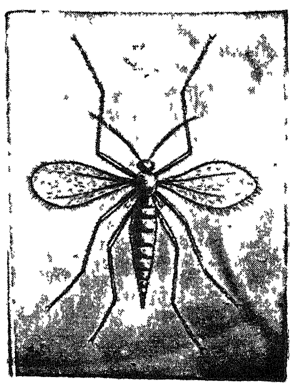


CRANE-FLY WITH OVIPOSITOR EXTENDED FOR DEPOSITING EGGS

It is no longer believed that the secretion poured into the wound made by the drill alone suffices. The fluid itself is supposed to act primarily as an adhesive security to retain the egg on the selected spot, and it is thought that the gall results from the after-effects — the wound, the presence of the eggs, the movements of the larvæ within the wound, and the action of a fluid secreted by the larvæ themselves, all tending to produce the strange modifications of cell-structure which manifest themselves in the various galls. Some such galls, it is needless to remark, have considerable commercial importance, notably that of the ink-gall of the Levantine oak, yielding 26 to 27 per cent of tannin. These insects constitute a study in themselves, their reproductive relations being especially interesting.



HESSIAN FLY



BRITISH WHEAT-MIDGE

Passing on to the Diptera, or true flies, we have here an order of two-winged insects. Formerly the members of the order were four-winged, but the second, or hind, pair of wings have become vestigial, and act now merely as balancers. How these perform their function it is difficult to say, but certain it is that a fly with its balancers removed loses all power of maintaining its equilibrium. This question of wings brings us to the buzz of the fly. It is commonly supposed that the sound proceeds from the wings alone, but there are two sounds — the first from the wings, the second from the exceedingly rapid vibrations of the thorax. The latter produce the higher note that we hear when a blow-fly is seized. That note is due to the fact that the vibrations of the thorax reach some thirteen hundred per second, while those of the wings are half that number.

The life story of the flies and mosquitoes has already been so fully treated in preceding chapters of this work that it would only duplicate the information to enter at length upon it here. One or two salient points may, however, be noted. The blow-fly lays its eggs in flesh, not necessarily dead flesh, for cases have been noted in which wounds, and even the nostrils of a sleeping man, have been selected. The domestic fly breeds in manure and decaying substances. It is a mistake to suppose that the small flies that we see are young flies. They are adult examples of their species and will grow no larger. House-flies are born from maggots, undergo their larval and pupal stages and emerge fully developed flies. How they carry corruption and infection has been shown elsewhere in this work. Before man became a sanitarian the fly

may have served a purpose as a scavenger; but as now it flits from its noxious feast straight to the food that he eats, and the milk that he and his children drink, the following figures, published by Dr. L. O. Howard, in his impressive volume on the subject, assume a specially sinister aspect.

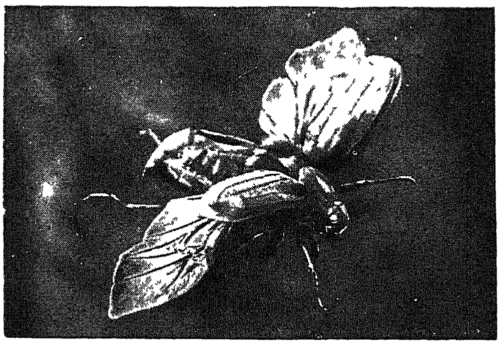
Beginning on April 15 with an overwintering fly, which on that date laid 120 eggs, he arrives at the following table, postulating that all eggs and all individual flies survive, and allowing ten days to a generation in summer.

April 15: The female lays 120 eggs.

May 1: 120 adults issue, of which 60 are females.

May 10: 60 females each lay 120 eggs.

May 28: 7200 adults issue, of which 3600 are females.



THE COCKCHAFER IN FLIGHT

June 8: 3600 females each lay 120 eggs.

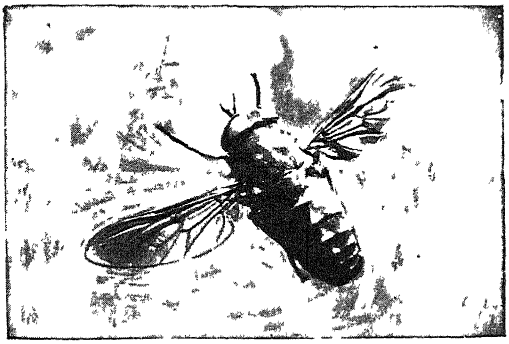
June 20: 432,000 adults issue, of which 216,000 are females.

June 30: 216,000 females each lay 120 eggs.

The table continues in this manner on to September 10, when 5,598,720,000,000 adults issue, of which one half are females

Of course, not nearly all the eggs or adults survive, but the table is illuminating as showing the terrible potentialities for increase possessed by a single fertilized female fly. There would be no lamentation on the score of extinction of a species should the last house-fly perish. A well-known public man, who is deeply concerned with the problem of child life in a busy northern city, lays it down as a business proposition that it pays that city better to provide the children of the poor with sterilized milk at the cost of the tax-payers than to meet the cost of funerals of poor children killed by fly-infected milk.

The habits of the gnats and mosquitoes have already been described, and need not be recapitulated, nor a word added to the tragic history of their death-dealing actions against man. Gnats and mosquitoes are one and the same, but midges, although allied to the others, are distinct. Although the hateful little black midge that bites at night rather gives the lie to the general statement, it is a fact that midges, taking the majority, do not bite, for the reason that they lack any blood-sucking apparatus. A curious thing has been observed of an Asian relative of the plumed midge (*Chironomous plumosus*)

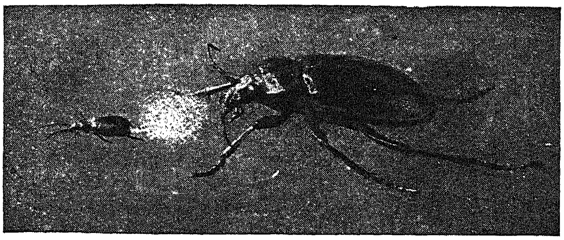


THE GREAT GADFLY

Vast numbers of these insects frequenting the shores of Lake Issyk-kul were found to be brightly luminous. The light emitted was due to the presence in the insects of multitudes of parasitic bacteria, whose presence prevented their hosts from rising on the wing. There is another true midge, however, *Ceroplatus sesioides*, which is luminous from natural internal mechanism, as in the case of the glow-worm, but here the light proceeds from the whole body of the insect, and is given off by both sexes.

The gall-midges are quite another group, and, with the so-called Hessian fly at their head, do incalculable damage to crops when in the larval stage. In this group we find an extraordinary case of reproduction by the larvæ. The gall-midge in question is *Miastor metroloas.* During

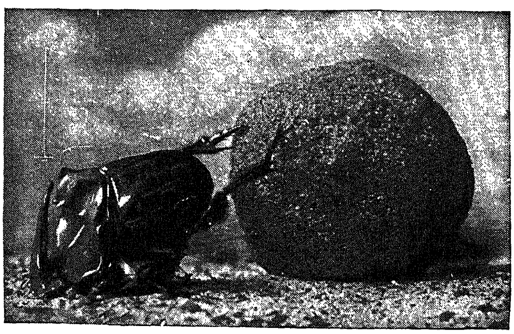
the summer reproduction follows the normal course, but, when colder weather sets in, the larvæ, which dwell under the bark of trees, develop living young within their bodies. These devour the vitals of the parent; then emerge, and themselves give birth to a generation in similar manner, and so the phenomenon continues until warm weather permits the life cycle to follow the extraordinarily unusual course.



A BOMBARDIER BEETLE REPELLING A CARNIVOROUS BEETLE BY THE EJECTION OF ACID

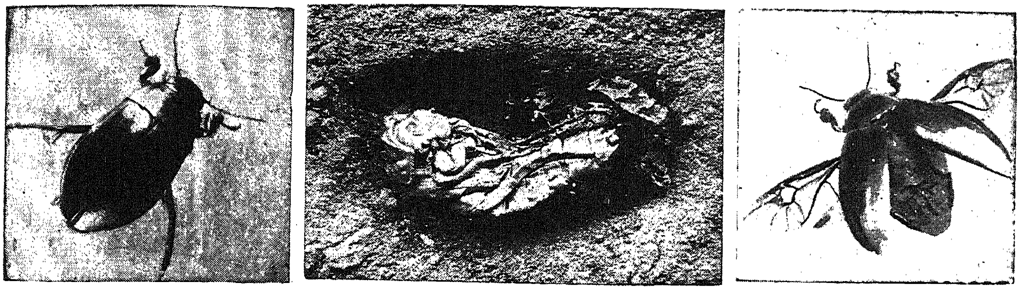
The sand-flies which follow are among the most venomous of enemies. Minute, difficult to discover, they have always been among the most dreaded of insects. Formerly some investigators thought that pellagra, a dreaded disease of the South, was spread by their bite, which gave rise to the opinion that pellagra was catching. Investigation by the United States Public Health Service has, however, proved that it is not so and that the disease is due simply to a faulty diet. People who consume a mixed, well-balanced, varied diet do not have it, and plenty of milk and lean meat will help defeat it if taken in time. Even so these insects and the deadly tsetse-fly, whose malevolent work has already been traced in another section of this work, are among the enemies to human life whose detection we owe primarily to the man who studies insects. If these and their like can be checked, or rendered innocuous — and the "if" is a mighty one — lands or parts of lands which are now extremely unhealthful may become numbered with the most flourishing places of the earth.

THE TENACITY AND FEROCITY OF THE DEVIL'S COACH-HORSE BEETLE IN ATTACK



A BRAZILIAN BEETLE ROLLING A BALL

But even among the flies which do not cause death we have enemies capable of great damage to commerce. Among these are the various bot-flies. *Gastrophilus equi* is a plague to horses, although its larvæ, which eventually find their way into the quadruped's alimentary system, do the animal no harm, so far as has been ascertained. The ox-bot, ox-warble or warble-fly, however, is a most pernicious insect; and cattle view it with instinctive dread, galloping from it in terror as the fly seeks to deposit its eggs upon their hide. Milk supply and flesh are thus injured, but the greatest damage results after the deposition of the eggs. The maggots which result eat their way through the hide and cause a small tumor, where they remain


THE WATER-BEETLE SWIMMING, IN PUPA FORM, AND FLYING

for nearly a year. As many as four hundred maggots of this fly have been known to issue from the skin of a single beast. The animal is tortured by the suppurating tumor, and loses flesh and condition, and its hide is greatly deteriorated in value. A careful estimate puts the loss to the leather trade from the warble-flies in this country at millions of dollars a year.

The sheep bot-fly is another formidable pest, and, numerous in genera and species and widely distributed, infests mammals of many kinds — including, on the evidence of two cases, man himself — and birds and even amphibians. The forest-flies are another strange group parasitic upon horses and cattle, which they bite upon those parts of the body least protected with hair. Some of the species attack birds; one species is parasitic upon deer. Beginning their career as winged insects, these insects bite off their wings on settling upon their hosts, after the manner of a queen-ant newly returned from her wedding trip.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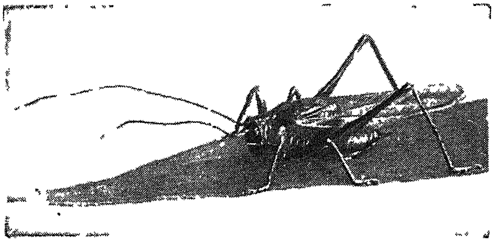
MOLE-CRICKETS IN THEIR BURROWS

In the forest-flies we find a remarkable method of development. Only a single young one is born at a time, and this, instead of being produced in the egg stage, remains within the body of the parent, nourished at her expense by means analogous to those which obtain in the higher mammals. When born, the young is either actually a pupa, or at once assumes the pupal form, being motionless, without segmentation, and inclosed in a horny case.

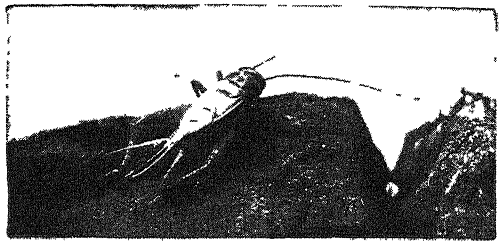
Fleas are only aberrant flies. They have no wings, but are descended from the ancestral stock from which the flies arose. The evil part that they play in the transmission of disease has already been shown. The flea is frequently the first host of the larvæ of a tapeworm. The ova are expelled from the body of the dog or cat; they are swallowed by the flea, which in turn is eaten by the dog or cat, in whose interior the life cycle begins again. Hence, if cats and dogs are kept about a house, they should be treated with the greatest care to prevent their harboring both the internal and the external parasites.

We can give but brief notice to the beetles, or Coleoptera, of which huge division some 130,000 different species have been described, while fully as many more, it is surmised, await the observer. There is a life's work here for the student, and a fascinating work, too. Greater diversity of form and habit it would be difficult to find in the realm of animate nature. We have beetles as small as the smallest pinhead, and, at the other end of the scale, examples such as the elephant-beetle, the

goliath, and the titan, six inches in length and proportionately broad Beetles play an important part in the daily affairs of the world. While we have, on the one hand, weevils destroying manufactured food, and hosts of other species taking toll of trees and growing crops, there are still more numerous hosts getting their living as scavengers and as snappers-up of innumerable other insects harmful to man. We find them boring deep into wood, living and dead. Their presence in dead wood has given rise to one of the most distressing of all the superstitions that go to make life unhappy. Because a minute beetle (Anobium) bangs his horny little head upon the woodwork of the furniture or other timber in which he has made his home, knocking to attract the attention of his lady-love, he is called the "death-watch" beetle, and the credulous call the sound the death-tick. Many an hour of deadly terror has been experienced in the silence of the sickroom when the signals of this innocent, if destructive, beetle have been heard. We have a fine brigade of carnivorous ground-beetles, and many interesting examples among them, none more so, perhaps, than the bombardier and his allies, which, when apprehensive of attack, audibly eject with explosive force a fluid which volatilizes, upon emission, into smoke. Another notable example of the Carabidæ is the violin-beetle, whose name is bestowed in relation to its singular shape. Next in order come the carnivorous water-beetles, of which the Dytiscidæ, the great water-beetles of our ponds and ditches, are familiar and shining examples.

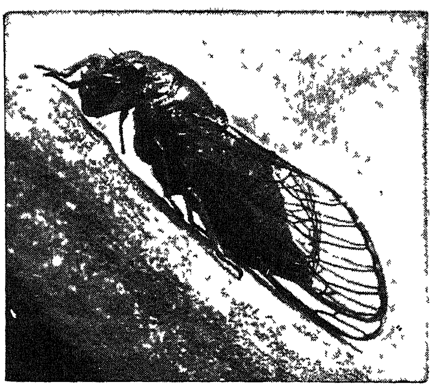


THE LARGE GREEN GRASSHOPPER



THE HOUSE-CRICKET

Well as we all know them, it seems hard to realize that these insects, so perfectly adapted to aquatic life, are notable fliers Passing nine-tenths of their time deep down in the water, thanks to their method of carrying down a bubble of air at a time, to be absorbed by means of abdominal and thoracic spiracles, they can at will rise into the air and fly across half a state in search of new quarters. You have but to dig a pool in the garden to be sure of finding water-beetles there in due season; or to examine the tank in a greenhouse; you will not be disappointed Equally common, though infinitely more attractive because of the brave show that they make on the surface of the water, are the whirligig beetles. These appear to have a stronger homing sense than the greater beetles, for you may put them on the water today, but if the circumstances do not suit them they will be off again at night, though ponds near by always teem with them.

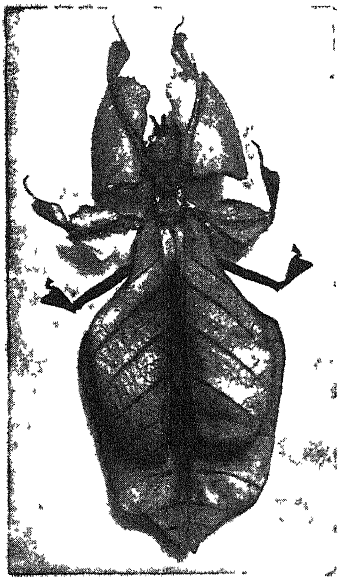


THE ENGLISH CICADA

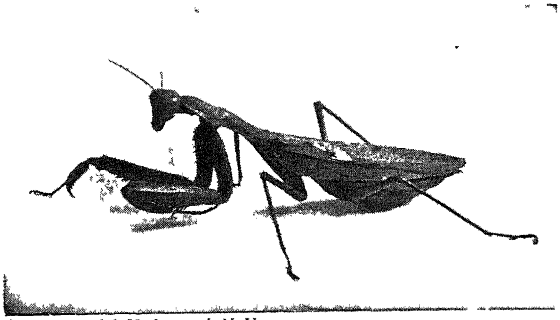
Although they are carrion feeders, the rove-beetles are not included among the carrion beetles proper. The roves, prominent among which is our admirable devil's coach-horse, are practically omnivorous. The inveterate enemy of caterpillars and other insect larvæ, they eat vegetable refuse as well as slugs and snails. The gardener has scarcely a better insect friend than this little, somber beetle with

the truculent fighting postures. The carrion beetles proper include the burying-beetles, which, attracted to the dead body of a bird or small mammal, dig away the soil beneath the carcass and gradually lower the latter until it is covered with soft earth. Then the female lays her eggs in the body, and the larvæ, when hatched, devour the flesh.

Of destructive beetles there is a long list, but the museum-beetle and allies (Dermestidæ) demand a place in our section, for in the larval form they work havoc with natural history exhibits, both furs, skins and dried insects, besides causing great damage in the home to furs, and also to hair-padded furniture.


A WALKING LEAF INSECT

The adaptability of some of the beetle tribe is indeed remarkable. One, *Lasioderma serricorme*, has given itself over to the consumption of cigars; a second has invaded the cigarette-box, while a third has become known as the drug-room beetle This (*Sitodrepa panicla*) is a desperate fellow, waxing fat on chemicals strong enough to poison an army. It is impossible to put it on a wrong diet, for it seems immune to all ordinary known poisons; the one plan feasible is to fumigate the parcel or bale of drugs which contains this most insidious foe.



THE PRAYING MANTIS

Our next group comprises the stag-beetle and its allies, whose larvæ pass years in the timber of oak trees before attaining the adult form. Large as are the stag-beetles, they are small compared with the larger members of the Lamellicornia, comprising the monsters to which reference has already been made. In this group we find some widely known species, such as the dumble-dor or shard-born beetles, and the chafers.

In concluding our mention of the beetles, two more varieties alone can be named. The first are the oil-beetles In these the larvæ display an almost incomparable instinct for gaining a living When hatched they are active little things, and climb without difficulty the stems of flowers, where they calmly await the arrival of a bee. When Brer Rabbit made a "riding hoss" of Brer Fox, he was but taking a leaf out of the book of these little creatures. For the oil-beetle larva, as soon as a bee comes its way, takes a firm hold of the honey-spinner's hair, and so rides away to the hive, where it diets itself upon the eggs of the bee, afterwards undergoing two stages of development and subsisting upon the choicest honey of the hive.

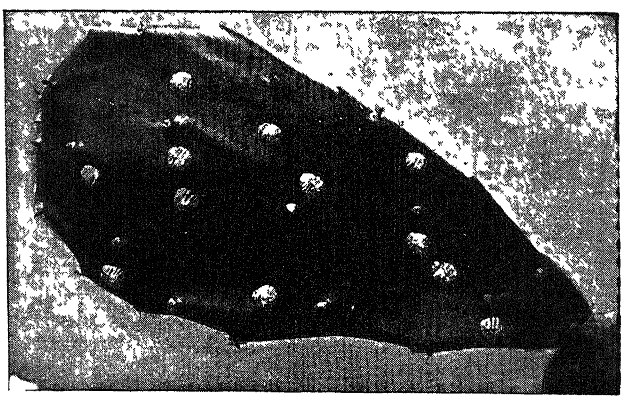
The last group is restricted to the Stylopidæ, or parasitic beetles. These are not to be confounded with *Claviger testaceus*, which makes its home in ant-hills; for the Stylopidæ live actually in the bodies of their hosts—bees, wasps and bugs. Here the female lays her eggs, from which emerge active little six-legged larvæ. These, quitting the depleted living storehouse in which they have hatched, complete their growth in the body of some new host. The male develops into a smart little winged beetle, leading a short and active life of a few hours only, or, in some species of a day, but the female never advances beyond the grublike condition and is eyeless, wingless and limbless.

Reference has been made to the value of ladybirds, in devouring aphids and plant-lice, and attention may be drawn to the interesting life stories of the ant-lion, the caddis-fly and the stone-flies. These lead us on to the true Orthoptera, in which we find such insects as the crickets, grasshoppers, the dreaded locusts, the leaf and stick insects (two of the most famous examples of adaptation to surroundings), the praying insects, or Mantidæ, the earwigs and the cockroach.

Locusts have, in past years, done great damage to crops in the United States. Economically the most important species here is the Rocky Mountain locust. In 1874 the estimated loss was 50 millions, when Colorado, Nebraska, Kansas, Wyoming, Dakota, Minnesota, Missouri, New Mexico and Texas were overrun by swarms, mostly from Montana and British America.

AN EARWIG EATING A DAHLIA LEAF

Many methods have been tried to exterminate these pests, with varying success. A fungoid parasite has been experimented with in parts of our country. Arsenic spraying, "locust screens" for catching the wingless larvæ, destruction of the eggs, rolling the infested ground with heavy rollers, have all done their share in the work. It is disheartening to find that, after all the efforts made, locusts in a recent year appeared in such multitudes that one swarm took ten days to pass a given spot, and a second took twenty-one days. The entomologist can conquer the locust, but he can only do so by the coöperation of men as skilled and assiduous over a wide area.



COCHINEAL INSECTS ON THE LEAF OF AN OPUNTIA

There are many other destructive insects, such as plant-lice, which include the aphids and the phylloxera, the deadly enemy of the vine; the cicadas, known as the seventeen year locust, since that period elapses between one generation of the winged insects and another; leaf-fleas, which puncture and drain leaves and buds of plants, and shrubs and trees; and scale, of which one species, *Icerya purchasi*, accidentally imported into the United States from Australia, threatened with ruin the entire orange plantations of California. The entomologists came to the rescue They went to Australia, studied the life-history of the pest on the spot, found that its natural enemies were certain dipterous and hymenopterous parasites, but chiefly the ladybird; imported and bred these, and cleared their orchards of the deadly peril.

In the Coccidæ (scale insects), however, are numbered some of service to man, notably the cochineal insects, which are, or until the discovery of synthetic dyes were, assiduously "cultivated" for their yield of coloring matter. The lac insect, from which we get lac dye and shellac, is another of the beneficial scale insects. There remain familiar parasitic insects such as those infesting the human and other mammalian bodies, but this is not the place for a dissertation on these revolting intruders. Our review of the insect world is necessarily suggestive rather than complete, but it may direct the student to a closer investigation of a subject teeming with vital interest.

MICROFILMING

First Aid to Crowded Archives

by

R. F. BECKWITH

IN the year 1870, when the Prussians and their German allies were besieging Paris, its inhabitants could neither receive nor send messages through the ordinary channels. Yet the flow of news into and out of the city was kept up throughout the siege because of the ingenuity of a French photographer named Dagron. He had conceived the idea of photographing messages on narrow strips of film. These were then developed and flown over the enemy lines by carrier pigeons. At the destination points, the tiny pictures were projected upon walls or other suitable surfaces; or else those receiving the messages read them through magnifying glasses. To Dagron's brilliant improvisation we owe the basic idea of a new and revolutionary method of duplicating printed and written documents and pictures — the method that we now call microfilming.

Men have always been concerned with the problem of duplicating records. A lost will may lead to years of bickering among the prospective heirs of an estate. A lost receipt may mean endless trouble for a man; an entire community may be affected by the loss of a town charter. More than one business firm has been forced into bankruptcy because its records were destroyed by fire, flood or earthquake. The only way to prevent mishaps like these is to duplicate our records, so that if the originals are lost, we may have copies to fall back on.

Up to the end of the Middle Ages, duplicating of documents of all kinds, in the Western world at least, was by hand. (It is said that the Chinese used movable wooden blocks to print official proclamations.) In the fifteenth century the invention of printing by Johannes Gutenberg enabled men to make thousands of copies of books and other documents in a fraction of the time formerly required.

Printing has been used since Gutenberg's time for the duplicating of documents, but only when a considerable number of copies are desired It costs as much to set type for one copy of a letter, say, as for a thousand copies; the cost of making a single printed copy would be very much higher than the cost of typing it The duplicating methods known as mimeographing and multigraphing are also practical only when a number of copies of an original are desired.

Up to a comparatively short time ago, the duplicating of records, in cases where one wished to have only one or a few copies, was entirely by hand — by writing or typing. This method is still used; but it has disadvantages. It is costly in time and errors often creep in; for the copyist is only human and he can not work with the accuracy of a machine.

Of late years, the photostatic method has marked an advance in the duplication of documents. In this process an exact photographic image of the original is produced upon sensitized paper. This duplicate, called a photostat, may be the exact size of the original, or smaller or larger. Photostatic duplication is quick, and it is accurate, since the camera lens can not lie. It is expensive, however, if used to duplicate great numbers of documents.

One of the chief objections to copying by hand, and by the photostatic method as well, is that the duplicates take up as much space (or about as much) as the originals. Government bureaus and business offices alike have been swamped with records that in some cases have been piling up for hundreds of years. As libraries grow, they find it more and more difficult to provide

Microfilming newspapers. The operator feeds a newspaper page from the stack at her side into the microfilming apparatus. The newspaper revolves around a drum within the apparatus, and as it turns it is scanned by the camera lens. Then it passes out of the machine and is replaced by another page.

shelf-room for new books, pamphlets, magazines and newspapers. Yet one can not simply destroy old records in order to make way for new ones.

The microfilming process — also known as microphotography — has solved the duplicating problem. As we have seen, the idea itself goes back at least as far as 1870; but the first practical microfilming apparatus was developed in the twenties of the present century by a New York banker, George L. McCarthy.

By microfilming we mean recording documents — book pages, letters, checks, maps, contracts and the like — on a narrow ribbon of film. The film is developed and stored away until needed, then it is enlarged by special reading devices.

The film used is made of cellulose acetate. It comes in two widths: 16 millimeters (about 3/4 of an inch) and 35 millimeters (about 1 3/8 inches). Sixteen-millimeter film, which is like that used in home movie cameras, is used for ordinary business documents, such as bank checks, cards, letters and legal papers. Bound

books and large documents, such as newspapers and engineering drawings up to $37\frac{1}{2}$ by $52\frac{1}{2}$ inches, are recorded on 35-millimeter film, the size used by many amateur photographers for their miniature cameras.

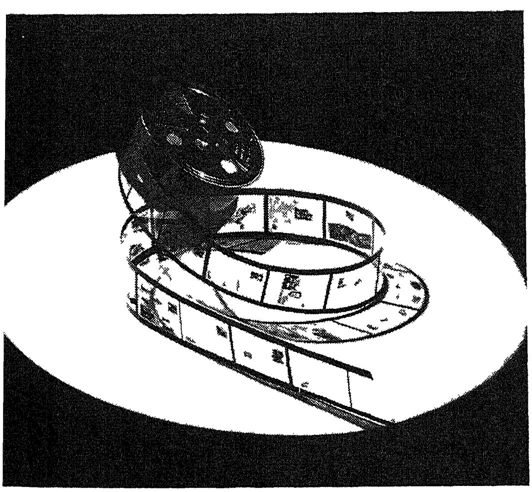
A reel of microfilm is loaded in the camera and the document to be photographed is brought into focus. As the roll unwinds, a small section of film is brought into position opposite the camera lens; an exposure is made, that bit of film is wound away from the lens, a new section takes its place and another document is brought forward to be photographed.

In the case of small documents, such as checks or receipts, the operator of the microfilming apparatus has only to feed the documents into the machine as rapidly as he can. In a single automatic operation the shutter clicks and the film is advanced the correct amount for the next exposure. Focus, light intensity, distance from lens to subject, diaphragm opening — all are fixed and require no adjustment.

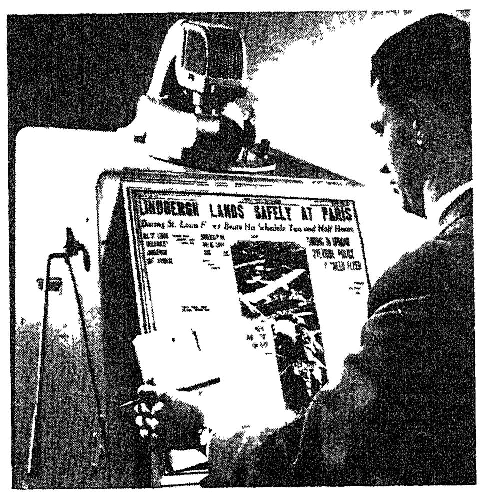
Large documents are laid on a flat surface and photographed by a special camera unit that can be raised or lowered on a supporting platform. Bound volumes can be photographed without removing the bindings. For this purpose the machine is provided with a mechanical book cradle that automatically brings the individual pages in turn beneath the camera lens. It is possible to photograph two pages simultaneously. Before the exposure is made, a beam of light is projected downward and outlines the exact area that is to be photographed. In this way, only the precise amount of film required is used for each exposure.

When the reel of film has been entirely exposed, it is removed from the camera and developed. We now see on the film a series of tiny images, separated from each other by a narrow border. Each image is greatly reduced from the size of the original; a document ten inches square can be reproduced on a tenth of a square inch of film.

When the film is developed, it is in the form of a negative; what is dark in the original is light in the negative and vice versa. Generally the developed film is left in negative form; it is wound on a reel and enclosed in a cardboard box, measuring about 4″ x 4″ x 1″. If a roll contains a number of unconnected items, it is sometimes cut into comparatively short lengths, which are placed, flat, in long, thin envelopes and stored in labeled boxes. Sometimes cut film is placed in cloth pockets,



This reel of film contains the complete issues of a big newspaper for a ten-day period. When the film is inserted in a reading machine, it is magnified to the size of the original newspaper.



Consulting an old newspaper, recorded on microfilm, in a large public library. The reader can work the film back and forth through the machine by means of the winding crank set at the side.

sewn on the backs of filing cards; the cards are stored in ordinary filing cabinets.

The tiny pictures are much too small to be read with the naked eye. Special projectors, called film readers, are used to magnify the images to a convenient size for reading. The enlarged image is projected on a translucent screen, where every detail of the original record is clearly and accurately reproduced. The reader can work the film back and forth through the film reader by means of winding cranks; in this way he can refer to any part of the film that he wishes.

Positive film prints may be made from the negative, of course. Paper prints in any size up to that of the original document, or even larger, can easily be produced from the negative by the ordinary photographic enlarging processes.

The advantages offered by the microfilming process

Microfilming offers many advantages over other methods of duplication. For one thing it is very rapid — far more so than any other duplicating method. It is error-proof, because documents are copied with the absolute accuracy of photography. It is economical, because the microfilm is inexpensive and because so many documents can be recorded on a single roll. It is durable; according to the United States Bureau of Standards at Washington, microfilm made of cellulose acetate will last as long as the best grade of all-rag paper.

Perhaps the greatest advantage of microfilm is that it occupies astonishingly little space. An operator can reproduce 21,000 cards measuring 3 by 5 inches, or 7,000 8½-by-11½-inch business letters, on a 100-foot roll of 16-millimeter film that can be held in the palm of your hand. A 1,600-page dictionary can be reproduced on a roll of film of the same size. A 4-drawer filing cabinet full of microfilm reels holds the equivalent of 50,000 bound volumes of ordinary size. A single safety-deposit box in the vault of a bank could hold all the confidential records of a great business enterprise, reproduced in microfilm.

Microfilming has so far found its widest use in business and industry. Banks microfilm canceled checks and bank statements, thus protecting both the bank and the clients against loss and fraud. Business houses microfilm their correspondence files and their accounts-receivable records. Engineering departments record their mechanical drawings and other data. When a leading electrical manufacturer microfilmed 2,000,000 old shop orders, sketches, drawings and charts, he saved an acre of floor space!

In some cases original business documents continue in everyday use after microfilms have been made of them, while the negatives are stored in safety-deposit boxes. In other cases, the bulky originals are destroyed, positives serving in the office or plant while negatives are stored safely.

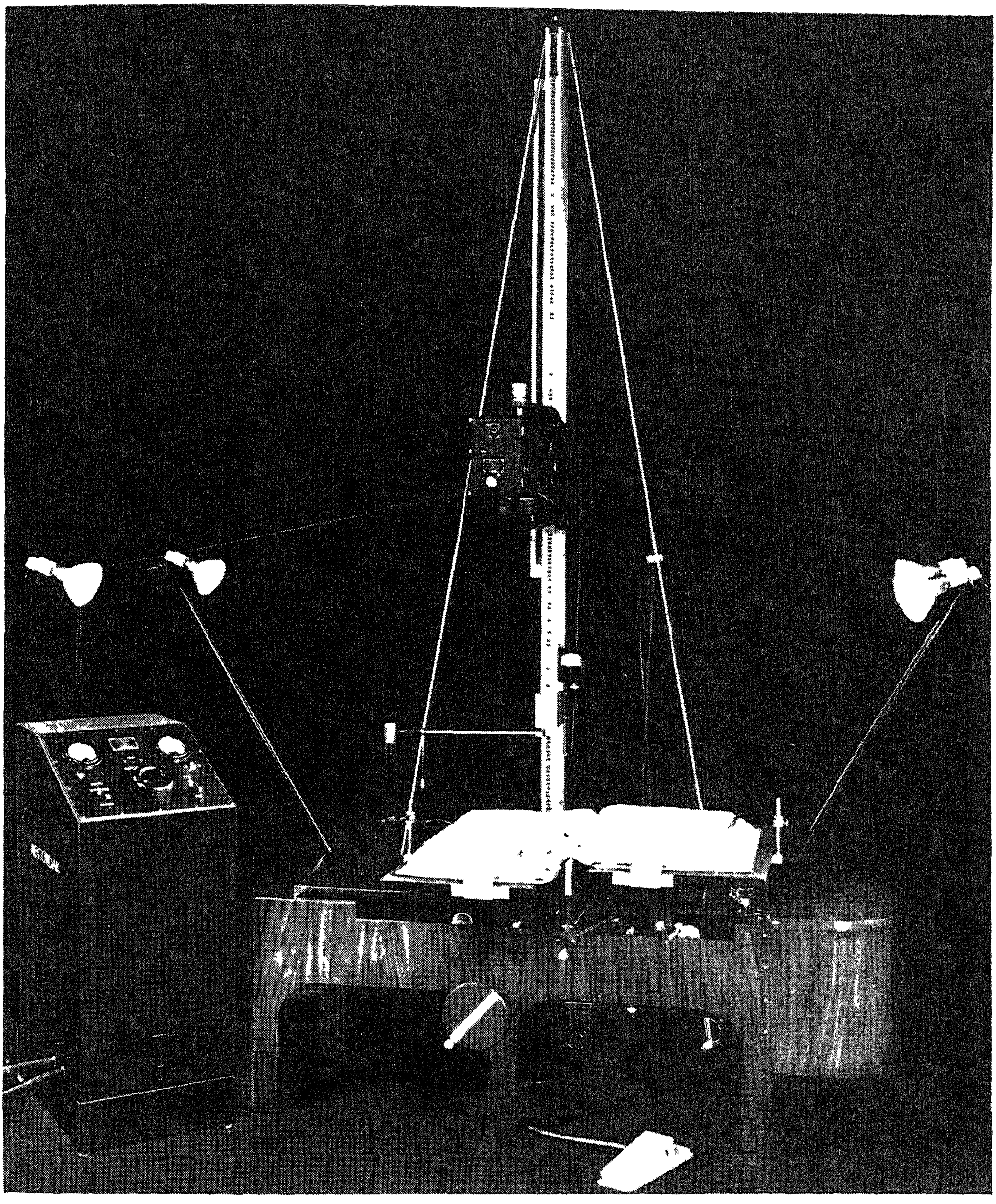
Some business houses and factories have their microfilming done by companies that specialize in this sort of service. The camera is generally set up in the place where the records are and reproductions are made while the ordinary business of the firm is being carried on. The films are developed by the company that provides the service. Other firms rent or buy their own microfilming equipment and train their employees to do all the work involved.

Federal government bureaus in the United States and Canada microfilm many of their records; so do state (or provincial), county and municipal agencies. Quantities of old records have been recorded on microfilm and then destroyed, thus releasing valuable space.

Why libraries have found it difficult to keep up newspaper files

Before the development of the microfilming process, libraries were seriously concerned with the problem of keeping up their newspaper files. Such files are very bulky and it is difficult to find space for them. Besides, newspapers have for years been printed on fragile sulfite and wood-pulp paper, instead of on rag paper, with the result that many of the old newspapers in the files have crumbled away.

Nowadays a number of leading newspaper publishers are having all current edi-



This rare old book is being microfilmed, page by page, so that its contents may be preserved after the book itself has crumbled away. The camera can be raised or lowered on a supporting platform; a mechanical book cradle brings the individual pages in turn directly beneath the lens of the camera.

tions microfilmed; some of them have had all their old issues recorded on microfilm. Newspapers sell positive film prints to other newspapers, local libraries and historical societies. The New York TIMES, for instance, now distributes over a hundred positive film prints of its issues; the master negatives of the papers are kept in a special atmosphere-controlled vault in the Eastman laboratories in Rochester, New York.

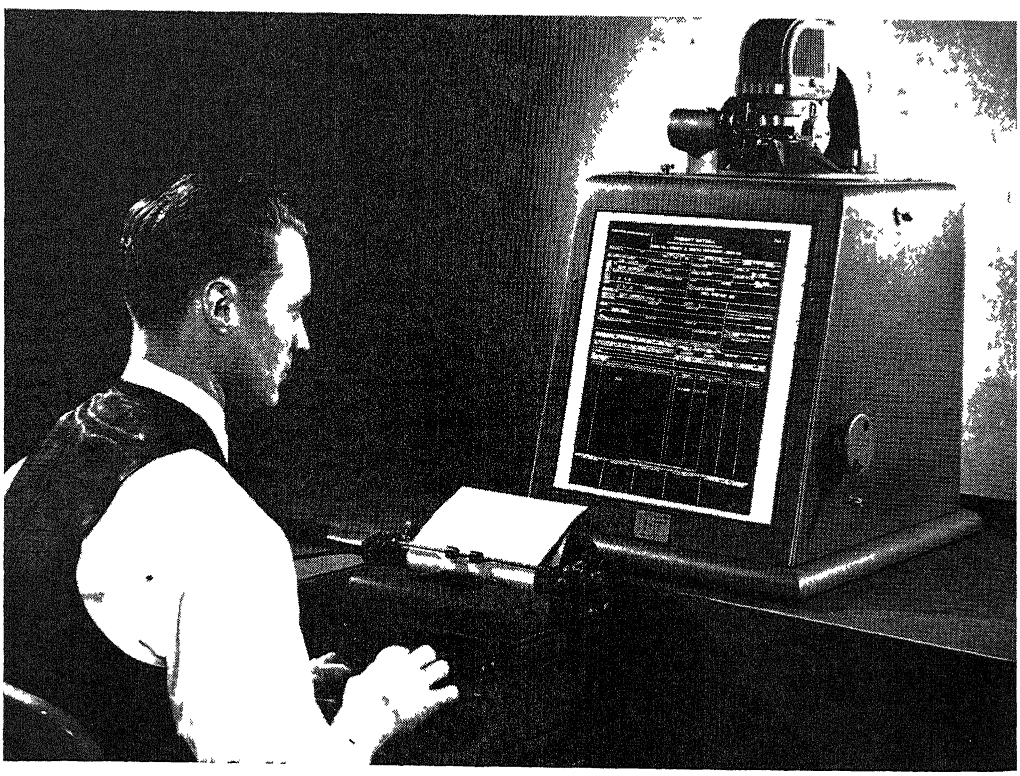
Every library has a certain number of rare books and manuscripts and also books that are too badly worn to be used by the

general public. Formerly, only a few people were permitted to consult them. Now a good deal of this material has been reproduced in microfilm and is available to all.

Formerly, scholars wishing to consult rare books or manuscripts in their own country or in other lands had to visit the libraries where these books or manuscripts were kept; or else they had to pay somebody to copy the contents by hand. When the photostatic method of reproduction was developed, scholars could have photostats made. However, the cost was far too high for the average scholar if he had to have many documents reproduced in this way. Nowadays a number of libraries are equipped to supply microfilm reproductions of any item included on their shelves or on the shelves of near-by libraries. The cost comes to only a few cents a page.

Sometimes microfilming of old manuscripts is done on a tremendous scale. The year 1950 saw the completion of such a project. Microfilm reproductions were made of over 2,000,000 pages of ancient manuscripts in the library of St. Catherine's Monastery, at Mount Sinai in Egypt. These documents, some of which go back 1,200 years, were made available for the first time to the scholars of the world.

Often, when we seek to learn about the civilization of past ages, we have to grope in the dark because so many ancient documents have been destroyed. Microfilming will make it possible to preserve for posterity a remarkably complete record of our own civilization and those that follow. A dramatic example of how this may be done was provided in 1939, at the New York World's Fair. The Westinghouse Time Capsule, a receptacle containing various exhibits of our civilization, was lowered into a crypt at the Fair; it was not to be opened again until 6939 A.D. — 5,000 years later. Among the contents of the capsule were

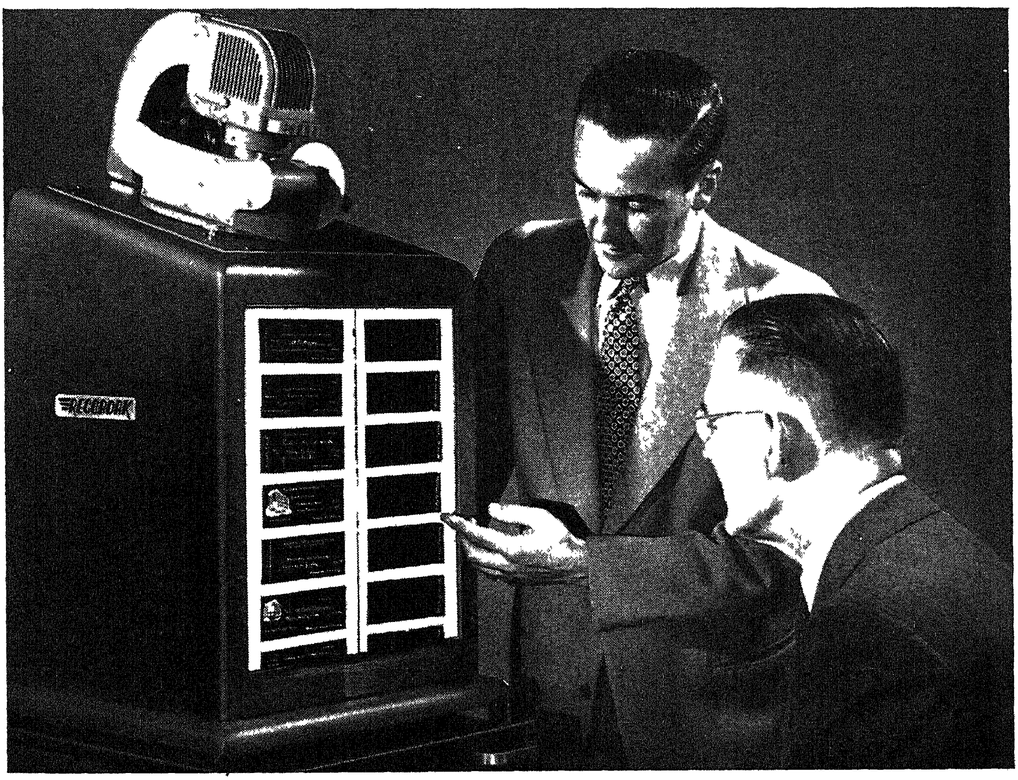


Consulting a microfilmed freight waybill in a railway office. Such waybills can be microfilmed within a few minutes and then turned over immediately to conductors, thus speeding up freight movement.

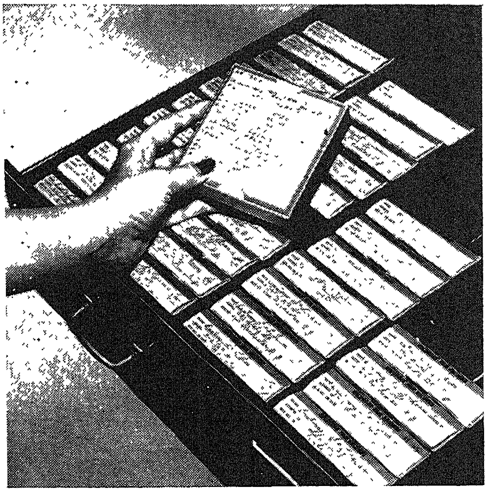
three and one-half reels of microfilm. On these had been photographed more than 30,000 pages of printed matter dealing with language, literature, science, government, industry, religion, entertainment — in short, a cross section of man's way of life in the year 1939.

During the early years of World War II, the libraries of England suffered terribly from aerial bombs; some of their most precious treasures were lost to mankind. To prevent further loss, a great number of books and manuscripts were microfilmed under the direction of the American Council of Learned Societies, with the full co-operation of the English authorities. The microfilmed material dealt with a wide variety of subjects — American and European history, law, the fine arts, music and literature. Copies of each microfilmed reel were deposited in Great Britain and in the Library of Congress in Washington, D. C.

Disputes between a department store and its customers over bills are readily settled if charge-account transactions are recorded on microfilm



Checks and bank statements are microfilmed before being returned to customers each month, protecting the bank and its clients against loss or fraud. Facsimile prints of canceled checks can be supplied.



Developed microfilm is left in negative form. It is usually wound on a reel and placed in a cardboard box measuring 4 inches by 4 inches by 1 inch.

Early in the spring of 1942, to speed mail to men fighting far away, and from these men to their homes, the British began photographing letters on microfilm; the films were sent to their destination by plane, and there enlarged and printed on paper. The British called this system Airgraph. In June of the same year the United States adopted the system, giving it the name of V-mail. During the war 321,000,000 letters were sent by Airgraph; 1,500,000,000 letters by V-mail.

Microfilming made it possible for the United States Navy to repair damaged warships with the utmost speed. Navy men had to have blueprints of damaged ships in order to make satisfactory repairs. Such prints are stored in the Washington headquarters of the Navy. They are very bulky; if the blueprints for a comparatively small ship like a destroyer were spread out, they would cover a quarter of an acre. Plans for a battleship would weigh more than a ton and would fill a boxcar.

If blueprints like these had been sent by ship, it might have meant a long wait before they reached their destination; or they would have used up a great deal of space on planes, at a time when such space was at a premium. Microfilming solved the problem. In Washington the drawings were microfilmed, and an officer was able to carry them by hand — and by air — to the repair station. In one instance, at least, this method proved so efficient that by the time the damaged vessel reached the port where it was to be repaired, new sections had already been fabricated and were ready to be installed!

Microfilming was used in espionage work during the war. Of course microfilm is an ideal medium for espionage, since it is absolutely accurate and takes up such little space.

In peace and war, then, microfilming has already proved its worth; and it offers many exciting possibilities for the future. It is no exaggeration to call the microfilming process the most important advance in duplicating the printed or written word since Gutenberg first began printing from movable types.

All photos, Recordak Corp.

The two piles of documents shown here, each as high as the woman in the picture, have been microfilmed. Their contents are now recorded on the eight reels of film that the woman is holding in her hands. The photograph shows dramatically how much space could be saved by microfilming records and then destroying the old documents.

KEEPING FIT

How to Care for the Body in Health

by
RUTH E. GROUT

NO two human bodies are alike. Some persons inherit strong, healthy bodies; if such people are properly guided in childhood and give their bodies proper care in later life, they will enjoy the maximum amount of good health, barring serious accidents or diseases. Others will never attain a full measure of health, no matter how careful they are.

Each person should learn what his own health assets and liabilities are and how to give his body the attention it requires, so that he may enjoy as great a degree of health as possible.

How to judge physical condition

The Health Examination. Thorough health examinations at definite intervals provide the most dependable method for finding out about one's physical condition. Children under one year of age should be taken to a physician for an examination every month. The preschool child should be examined every three months; the school child, at least once a year.

The young man (or woman) between twenty and thirty-five years of age ordinarily does not need to have a complete examination more than once in two years. He has reached his full growth, for one thing; besides, he is not likely to be affected by the common ailments of later years. By the time he is thirty-five, an annual examination is desirable. Beyond the age of fifty, when cancer, heart disease, kidney trouble and other similar diseases are most likely to occur, a checkup twice a year is advisable.

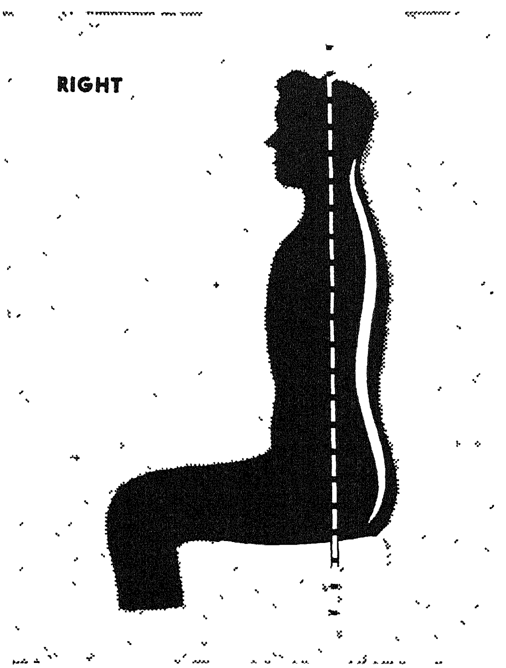
The Dental Examination. Dental examinations are essential in order to control tooth decay. They should be made by a competent dentist annually or at more frequent intervals, starting at the age of two and continuing throughout one's life.

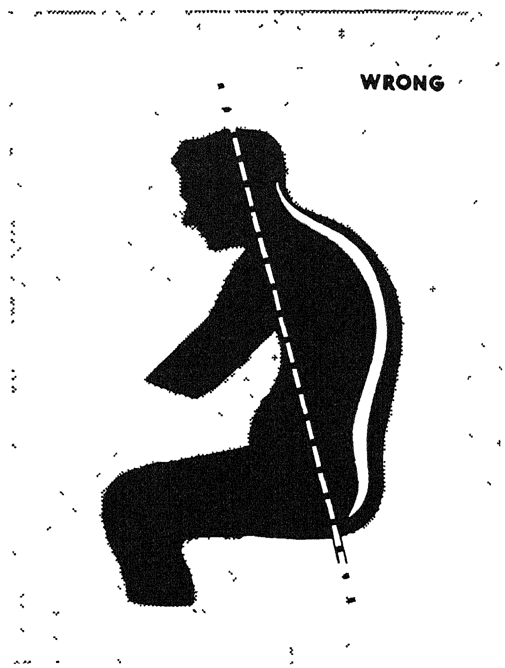
Taking the Body Temperature and the Pulse Rate. Body temperature and the pulse rate are clues to the state of health. The physician uses them to aid his diagnosis; a layman, to decide whether or not it is advisable to consult a physician.

The Signs of Good Health

There are certain signs of good health:
Hair: glossy; clean.
Eyes: bright; clear; move normally; vision normal.
Ears: free from infection; no discharge or pain; hearing not impaired.
Skin: good color; smooth texture; free from blemishes.
Teeth: clean; no unfilled cavities; properly aligned.
Muscles: firm; well-conditioned.
General Appearance: alert; good posture; no nervous symptoms; not too thin or too fat.
Other Signs: good appetite; no undue fatigue after exertion; refreshed by rest.

Body temperature is taken with a clinical thermometer. The temperature of adults and older children is nearly always taken by placing the thermometer in the mouth. A special kind of thermometer, which is inserted in the rectum, is used for babies and small children. In health, the temperature will read about 98.6° when taken by mouth; however, the reading will generally vary slightly from this standard at different periods of the day. In a child, a rectal temperature of 99 degrees is within the





Both diagrams, Posture Research Institute

Correct posture helps young and old to keep fit. Incorrect posture may bring about bodily ills.

limit of normal variation. Body temperatures also vary with different individuals. Generally speaking, one should consult a physician if the temperature is 100° or more; however, in certain cases, medical care is required even if the temperature is not so high as that. In other words, body temperature is only *one* of the factors that should be considered.

The expansion and contraction of the arteries as the blood flows through them is known as the pulse; it can be felt best in the arteries that lie near the surface and close to a bone, as at the wrist or the temples. Pulse rates vary according to age. They are higher in children, until the age of puberty (sexual maturity) is reached, than in adults. Women have higher rates than men. The rate for women averages about seventy-five to eighty beats per minute; for men, about seventy beats a minute. Anger, fear, excitement and increased physical activity will cause the pulse rate to increase; the rate will also be faster when the body temperature rises. If the pulse rate is far above the average, a physician should be consulted.

The Use of Height-Weight Tables. A common method of determining one's general physical condition has been to compare one's height and weight with standard tables of average heights and weights at different ages. Any wide deviation from so-called "normal" height and weight is supposed to show that something is wrong. The tables have also been used to determine whether a child is growing properly.

Scientists now know that deviations from the average weight for a given height and age, as shown by these tables, may be perfectly normal for an individual. Some people who appear to be underweight may be small in build but are in excellent health; others who seem to be overweight have large skeletons and they too are healthy. Still others who have "normal" weight, according to the standard height-weight tables, may really weigh too little for their build, or they may display certain symptoms that indicate poor health.

Growth as an Index of Health in Children. The study of a child's own growth record or the growth records of other children is now considered the most dependable

method of judging his physical progress. Regular gain in weight and in height is a sign that he is developing as he should, while failure to gain in weight for three successive months or more usually means that something is wrong. In keeping records, weights should be recorded monthly; heights, two or three times a year.

The care of the teeth and mouth

Sound teeth and a clean mouth add to personal attractiveness and contribute to good health. Poor teeth and gums interfere with the digestion of food. Missing or crooked teeth may cause speech defects; unpleasant facial expressions may result.

If food becomes lodged between the teeth and is not removed, it gradually disintegrates and produces bad breath. (Bad breath may also be caused by conditions that have nothing at all to do with the teeth, such as indigestion, diseased tonsils and nose infections.)

The most common cause of poor teeth is dental decay, known as dental caries. It is particularly widespread in children. It has been said that 97 per cent of the people in America at some time or other have cavities, caused by decay, in their teeth.

At the present time, there is no known method of care that will wholly prevent dental caries, but certain things may be done, nevertheless, to control its effects.

Early and frequent dental care is the most dependable method of dealing with this condition. As we remarked before, regular visits to the dentist should begin as early as the age of two. The dentist will fill any cavities he finds before they have had a chance to cause too much damage to the teeth. When decay is left unchecked, it spreads through a tooth much as rot spreads through an apple; it may finally cause the loss of the tooth.

Frequent visits to the dentist during childhood are advisable for another reason. The dentist will have a chance to see whether or not the child's teeth are coming in straight. If necessary, they can be straightened through orthodontia (dentistry dealing with irregularities of the teeth), so that each tooth will have room to grow as it should.

Particular attention should be paid to the six-year molars. These are the first permanent teeth to appear in the mouth; as the name implies, they come through about the sixth year. They should be preserved at all costs. If any one of them is extracted, it leaves a gap so that the other permanent teeth come in crooked.

A good diet is necessary for the formation of good teeth during growth. After the teeth have been formed, a well-balanced diet is essential for good general health, including the health of teeth and mouth. The diet should include adequate amounts of milk, vegetables, fruits, meat or fish and whole-grain cereals.

There is increasing evidence that a diet that is rich in sweets favors the growth of germs that cause dental decay. Cutting down on candy, pastries, sweet drinks and sugar-coated gum will help to check caries.

Brushing the teeth may help prevent a certain amount of dental decay. The teeth should be brushed after every meal. Unfortunately, the old saying that "a clean tooth never decays" is not very accurate.

Mothers should begin to brush their chil-

U. S. Public Health Service

Applying a 2 per cent solution of sodium fluoride to children's teeth will reduce tooth decay.

dren's teeth by the age of two years. By the age of three, children should be able to brush their own teeth. The toothbrush should be small. An approved type for any age is one that is no more than six bristle-tufts long and two wide.

Commercial tooth powders and toothpastes are pleasant to use, but have no special virtue in the cleansing of teeth. Many dentists recommend finely precipitated chalk or bicarbonate of soda as safe and inexpensive substitutes.

It is said that rinsing the mouth (water is sufficient) after eating — particularly after eating substances containing sugar — will cut down caries. Mouth washes have little effect in the control of dental decay. They do help to remove particles of food from between the teeth; but, after all, a water rinse will have the same effect.

No matter how carefully the teeth are cleaned at home, tartar and other deposits or stains will accumulate on them. The only satisfactory way to have these stains removed is to have the teeth cleaned by the dentist, once or twice a year.

An interesting development in the control of caries is the use of a fluoride (compound of fluorine). It may be taken internally through properly treated drinking water, or it may be applied directly to the teeth by the dentist. Experiments have shown that dental caries in children whose teeth are developing has been reduced as much as 60 per cent by the use of the treatment. It does not check caries in adults. It is important to note that it should be used only under expert supervision.

Ammoniated toothpastes and powders, which set ammonia free in the mouth, have also been used as antidecay agents.

The care of the eyes

In general, the eyes furnish their own hygienic care. Eyelids cover the eyes when there is danger; when the eyes close, a protective secretion is spread over the inside of the lids. Tears and eyelashes provide further protection and help to keep the eyes clean. All of these mechanisms work automatically.

General body health has an important bearing on good eye health; when the body is in a run-down condition, the eyes likewise are below par.

Eyes should be examined periodically by a qualified physician and if possible by an oculist, or ophthalmologist — a physician specializing in the treatment of defects and

Better Light Better Sight Bureau

A poor lighting arrangement: the lamp produces a comparatively small circle of light on the desk.

diseases of the eye. If visual defects are discovered, they should be corrected at once. Otherwise, they may cause great discomfort to the eyes and may also produce dizziness and other disturbances.

Adequate lighting is important; there should be enough light and also the right kind of light, so that the eyes do not have to strain in order to see. Light is measured in terms of foot-candles. A foot-candle represents the amount of light that a sperm candle, made according to a definite formula, will throw at a distance of a foot. A minimum of fifteen foot-candles of light is needed for ordinary reading in the home; at least twenty-five foot-candles are required for close work such as sewing.

Glare has a very fatiguing effect on the eyes. Opaque lighting fixtures that reflect the light upward as well as outward help to prevent glare; exposed electric-light bulbs and clear-glass oil-lamp shades produce glare and cause much eye discomfort and strain.

Prolonged use of the eyes produces eye fatigue. It is a good idea to lift one's eyes occasionally from close work and look off into the distance, or to rest one's head on the desk or table. Sleep and other forms of rest and relaxation also help to reduce or eliminate eye fatigue.

The introduction of television in many homes has produced a new cause for eye fatigue. A clear image on the screen will minimize such fatigue. There should not be too great contrast between the light on the screen and in the room. Moderate, indirect lighting makes a good background for viewing television. Shifting the gaze away from the screen at frequent intervals will cut down eye fatigue considerably.

Many eye difficulties arise from infections and injuries. External infections often are spread as a result of careless personal habits, such as using another person's towel or rubbing the eyes with unclean hands.

Suitable precautions should be taken to protect the eyes from injury on the playground, in the factory or wherever they are exposed to danger.

A physician should be consulted whenever there is trouble. Granulated eyelids (trachoma), styes, conjunctivitis (an inflammation of the membranes covering the front of the eyeballs and lining the eyelids), foreign particles in the eye, continuous headaches and red eyes are among the abnormal conditions that demand medical attention. The use of eyedrops and eye-

Better Light Better Sight Bureau

A good lighting arrangement: the light, effectively diffused, illuminates every part of the desk.

washes should be avoided, unless the physician orders them. If glasses are prescribed, they should be worn as directed.

The care of the ears

The saying that "nothing smaller than the elbow should be placed in the outer ear" is not so nonsensical as it might appear to be. Certainly, the practice of cleaning the ear with hairpins, toothpicks or other sharp instruments should be avoided. It may result in the infection of the ear canal or in damage to the eardrum.

Wax that accumulates in the outer ear should be removed by syringing it out gently with lukewarm water. Before attempting to do so, a person should obtain instructions from a physician or a nurse.

Infection of the middle ear, the part that lies behind the eardrum, may be the result of a spread of infection from the nose and throat through the Eustachian tube to the middle ear. The ear will ache, and hearing will be affected. Early medical diagnosis and treatment of an ear infection are extremely important. If left untreated, not only may the ear itself become permanently damaged but the infection may spread to the mastoid bone and from there to the brain.

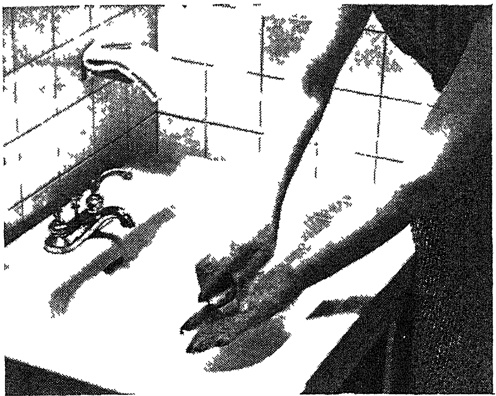
Periodic hearing tests will reveal early hearing losses. These tests should be given frequently enough so that any defects in hearing may be detected before they have progressed too far to benefit from treatment. The instrument known as the audiometer is particularly useful in detecting hearing losses; communities should purchase the instrument for schools and health centers. All those who are found to have hearing loss should be referred to a physician for further examination and for treatment if necessary.

Sonotone Corp.

Giving a hearing test with an audiometer. The instrument detects and measures hearing losses.

The care of the nose

The nose serves as a passageway for air to the lungs. As the air passes through, it is warmed and moistened; it is also cleaned



Cleanliness Bureau
A scrubbing brush is useful in washing the hands

by means of a great number of tiny cilia, or hairs, within the nose. These protective devices are more efficient than any that we can provide.

Blowing the nose is helpful in removing mucous secretions, dust and various other particles. The nose should be blown with both nostrils open.

Self-medication by means of jellies, sprays, drops and douches is a dangerous procedure. Preparations like these may give temporary relief, but have no lasting value. They may even interfere with the normal protective activities of the nose and they may cause chronic irritation.

The nose is connected by small passageways to the sinuses; these are cavities within the skull, located in the vicinity of the eyes and nose. Infection in the nose can spread rapidly to the sinuses. Although acute infections of this sort often clear up spontaneously, chronic infections may cause much discomfort and ill health. Diagnosis and treatment of sinus infections should be entrusted to a physician.

Children often stuff pennies, chalk, buttons or various other foreign bodies in the nose. Parents should never attempt to remove foreign objects like these themselves, but should seek the aid of a physician.

The care of the hands

Cleanliness of hands and nails is important from the standpoint of good grooming and, to a certain extent, from the standpoint of good health. Hands should be washed as often as necessary, the number of times a day will depend on the person's occupation. Hands should be washed before handling food, before eating and after going to the toilet They should be rubbed thoroughly; plenty of soap and warm water should be used.

Too-frequent hand washing may result in the removal of natural oils and may cause rough, cracked hands Lotions help to keep the hands soft

The care of the nails

Nails reflect the state of a person's health. Diseases like diabetes, typhoid fever, valvular heart disease, asthma and syphilis may cause changes in the color, texture and shape of nails. Brittle, cracked nails may be due to a deficiency of vitamins, iron or other elements in the diet; they may also be caused by too frequent use of nail-polish remover. Nervous persons are apt to bite their nails Before this particular habit can be broken, the underlying conditions that cause it must be corrected.

Regular manicuring will help to prevent hangnails The cuticle (the skin around the base and sides of the nail) should be pushed back frequently, especially after washing the hands, while the cuticle is soft.

The care of the feet

Foot difficulties are the cause of much fatigue and also of various other disturbances. Comfortable, properly fitted shoes will help keep the feet in good condition. Good general body health, good posture and cleanliness are also important.

Shoes for everyday use should fit properly. A shoe that is too short will cramp the foot; one that is too long will be just as uncomfortable. In general, shoes should have round toes and straight inner borders; they should be of medium width. The heels should be neither too high nor too low. High heels for women are all right for dress occasions, but they are bad for the feet if worn every day. Very low-heeled shoes, like moccasins, do not give the foot

The hair should be brushed thoroughly twice a day.

enough support. Most feet require the firm support that is provided by rigid shanks.

Faulty shoes may cause ingrown toenails, corns and calluses and other defects. Ingrown toenails occur usually on the big toe; the edge of the nail penetrates the flesh and often causes infection. Treatment for this condition is a local operation, with partial removal of the nail. To prevent ingrown toenails, the nails should be cut straight across. When troubled with corns, one should find out which piece of footwear is causing the difficulty and promptly stop wearing it. Corns are not easy to cure; they are likely to reappear when pressure is applied again.

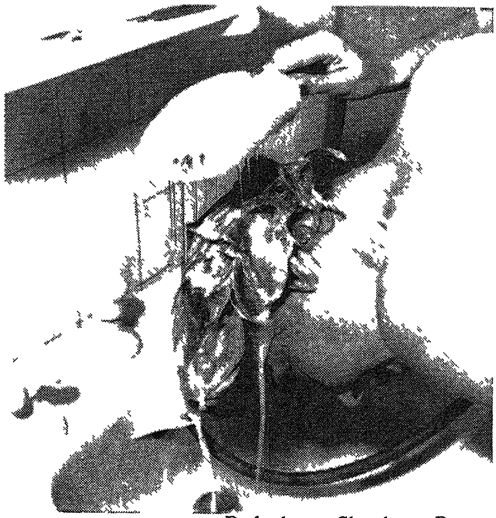
Weight control has a definite bearing on foot hygiene; people who weigh too much are likely to have foot difficulties, as the feet cannot support the extra load. Proper posture in standing and walking are also important; so is cleanliness. The feet should be bathed daily with a nonirritating soap, and they should be dried thoroughly. Tired feet should be soaked alternately in hot and cold water.

The care of the hair

Dirt, dead skin cells and oil secreted by the scalp accumulate on the scalp and in the hair. They can be removed by brushing and shampooing.

The hair should be brushed thoroughly twice a day; this not only helps to remove dirt but it also serves to stimulate the scalp. A stiff brush, with its bristles set apart, is desirable.

Frequency of shampooing depends upon the condition of the scalp and the amount of exposure to dust and dirt. Oily hair should be washed once a week or oftener; dry hair may not have to be washed more than once every two weeks.



Both photos, Cleanliness Bureau

For sparkling cleanliness, the hair should be rinsed thoroughly in warm, then cold water. Plenty of clear water should be poured over the hair.

Use plenty of soap (or detergent) and of warm water. The soap may be in the form of a solution, a cream or a powder. Soap cake rubbed directly onto the hair is hard to remove later when the hair is rinsed. Usually two soapings are desirable, the first to remove the excess oil and the second to clean the hair and scalp thoroughly. Several rinsings are necessary to remove all the soap. Clean, wet hair will "squeak" when rubbed between the fingers. Excessive heat should be avoided in drying the hair; it is better to use a towel or simply to expose the hair to the air.

Permanent waving has become a very common practice among women today. Are permanent waves harmful to the hair or scalp? The following statement by the Bureau of Investigation of the American Medical Association answers the question:

"Both the machine- and machineless-wave solutions consist chiefly of ammonia, the machineless solutions also containing various sulfates, as a rule. The cold-wave preparations do not greatly differ from one another in composition, usually depending on ammonium salts for softening the hair and ammonia for the waving effects.

"Though all three types have been reported to have caused injuries in individual cases, considering the millions of such treatments given to American women annually, it seems likely that the proportion of injuries is small, though, of course, not all of them may have been reported.

"The cold-wave solutions apparently have come into popularity in very recent years, as the inquiries about them are now more numerous than those about the heat-wave preparations. A government agency which investigated some of them expressed the belief that most of the difficulties resulting from their use are due to carelessness on the part of the beauty-shop operator or of the user in applying them, chiefly because proper warnings are not given with the directions that accompany the products. The government agency further warned that care should be taken not to let the solutions touch the scalp or skin, lest they enter the system and cause some internal injury."

The problem of elimination

Body wastes are eliminated through the intestines and kidneys and also by way of the skin and lungs. The healthy body handles its eliminative processes with a minimum amount of attention.

Ordinarily, constipation, or delay in elimination, can be avoided by a balanced diet, regularity of eating habits, the drinking of plenty of fluids, adequate rest, exercise and freedom from emotional strain.

Each person has his own bowel habits. For some persons it is perfectly natural to have a bowel movement only once in two or three days; for others, it is normal for the bowels to move two or three times a day. It is important to heed the call of nature whenever it occurs; ample time should be allowed for complete evacuation.

Laxatives and cathartics may give temporary relief, but they often do more harm than good. They should never be used if there is any abdominal pain. Such pain may be the first symptom of appendicitis; purgatives may cause irritation and even rupture of the appendix. Special drugs to aid elimination should be used only as directed by a physician.

The care of the skin

A simple, well-balanced diet helps to keep the skin smooth, free from blemishes, in good color and functioning properly.

Cleanliness is essential for a healthy skin and a good complexion. In general, the average person should take a cleansing bath with mild soap and warm water daily. This removes the waste materials excreted by the body through the skin; it also eliminates excessive oil and the dirt that has collected during the day.

The face and hands should be washed oftener than the rest of the body. Hand washing has been discussed earlier in the chapter. Wash the face very thoroughly at least once a day, preferably at night, with a mild soap and warm water applied with a wash cloth. In the morning, a rinsing with warm water, followed by cool water, may be enough.

Oily skins will need more frequent cleansing than dry skins. If the skin is bathed too often, it may become excessively dry, chapped or inflamed; this is true particularly during cold weather. The skin will become similarly irritated when the soap used in bathing is not rinsed off completely.

Soap is the most satisfactory of all cleansing agents. In former years, soaps contained free alkalis, which caused considerable irritation, but such alkalis are generally absent in the complexion soaps sold today.

The skin disorder called acne is common in young people. In acne, the pores of the skin and the openings of the oil glands become clogged, and this condition results in pimples and blackheads. It is now be-

lieved that glandular secretions within the body play a very important part in the development of acne. In mild cases, thorough washing with plenty of soap and warm water is helpful. Severe cases require expert treatment by a physician.

The use of cosmetics

Many millions of dollars are spent annually on cosmetics. Though many of these products serve a useful purpose, nothing can take the place of health as a source of genuine beauty. Good health produces fresh complexions and smooth, firm skin; it also causes cheeks to glow and the eyes to shine. Cosmetics may be used to enhance these effects; they should never be used as a substitute for nature's methods.

Most of the cleansing creams, cold creams and lotions that are now on the market are harmless to the normal skin. Cleansing creams are of different kinds. Some of them are merely soap and water in cream form; others contain mineral oil; still others are chemicals known as detergents. (See the article on Soaps and Synthetic Detergents at Work in this volume.) Detergents make the most effective cleansing creams; they are gradually replacing the other kinds. According to advertising claims, hormone creams preserve youth; they are dangerous and should be avoided.

Cold creams and face lotions have been used to cleanse or lubricate the skin since time immemorial. These cosmetic preparations do not cause superfluous growth of hair, as some people believe, but they definitely cannot bring about the miracles that are sometimes claimed for them. Names like "nourishing creams," "wrinkle eradicators," "skin tonics," "contour creams" and "tissue creams" are quite inaccurate and misleading.

The use of deodorants

Body odors are caused by an accumulation of sweat or oil on the body's surface. Regular bathing to remove these substances and change of underclothing following the bathing are the best methods to keep down the odors. When sweating becomes excessive, as under the arms, it may be desirable to use a deodorant. Some deodorants cut down the action of the sweat glands; others merely reduce or counteract the odor of sweat. A simple, inexpensive underarm deodorant of the latter type is ordinary baking soda.

Many people can use deodorants without harmful effects. If they irritate the skin, one should either change the product or seek medical advice.

The use of depilatories

Excessive hair on the face, legs and armpits often causes annoyance to women. Various methods, both temporary and permanent, are used to remove this hair.

The only safe method for the permanent removal of hair is electrolysis, in which an electric needle is used. It is important to note that this method should be employed only by skilled operators.

Hair is sometimes removed temporarily by chemical or mechanical devices. The chemical method, which involves the application of a substance that dissolves the hair, may damage the skin. The chemicals may also be absorbed and do harm to the body. They are not recommended.

Hair may be removed mechanically by means of tweezers, by shaving and by a mild abrasive, such as sandpaper or pumice. The tweezers method is satisfactory for removing single hairs. Over wide surfaces, shaving or the use of an abrasive is preferable. Another procedure is to cover the surface of the skin with wax and then to strip off the hardened wax, thus pulling out the enmeshed hair. This method may be irritating; it is not more effective than the rest.

Keeping abreast of new developments in medicine and public health

New developments in medicine and public health add constantly to our understanding of the care of the body. Everybody owes it to himself, to his family and to his community to keep abreast of these developments and to apply them if possible.

EXERCISE AND REST

How the Body Expends and Renews Its Stores of Energy

by
A. C. BURTON

IN certain respects, at least, the human body is like an engine, for it is constantly transforming the chemical energy contained in its "fuel" — its food — into heat energy and mechanical energy. The toast you eat for breakfast is burned in the body, just as coal is burned beneath the boiler of a steam engine or gasoline is burned in the cylinders of an automobile. Part of the chemical energy supplied by the toast is changed into the heat energy that keeps your body warm; part of it, into the mechanical energy utilized when your muscles pump blood through your body or move your chest in breathing.

Bodily activities that go on at all times

Even if you lie idly in bed all day, your body continues to transform a certain minimal amount of the chemical energy provided by food into mechanical energy and heat energy. The heart keeps on pumping blood in the circulation; the lungs continue to contract and expand in order to draw in oxygen and discharge the waste products carbon dioxide and water; the movements of the intestines continue as food is digested. The body must be kept at its normal temperature so that activities like these may be carried on as effectively as possible.

The rate at which your body transforms energy when it is at rest is called its basal metabolic rate. (See Index, under Metabolism.) It may be compared to the greatly reduced rate at which an automobile engine consumes gasoline when it is idling. In the basal, or resting, state of the body, most of the chemical energy provided by food is changed into heat energy and only a little into mechanical energy, since most of the muscles are relaxed and inactive.

When you rise from your bed and go about your daily activities, the rate at which energy is transformed by the body increases greatly. Even when you are simply standing still, the muscles that have to do with posture must exert themselves in order to hold the body upright.

The transforming of chemical energy into mechanical energy by the muscles is called muscular exercise. We generally think of exercise as the kind of activity that is involved in playing a game of tennis or running a race or carrying the puck in a hockey game. Scientifically, however, the term refers to any form of muscular activity, violent or gentle.

How much energy is used in exercise?

No engine is perfectly efficient, since a good deal of its chemical energy is transformed into heat energy instead of mechanical energy. In the case of the human body, only about one-quarter of the energy we obtain from food is changed into the energy required for breathing, talking, walking, writing and the like. The rest is changed into heat energy.

When the muscles become active, more chemical energy is required so that increased mechanical energy may be made available. The following table shows the energy increase involved in different kinds of muscular exercise:

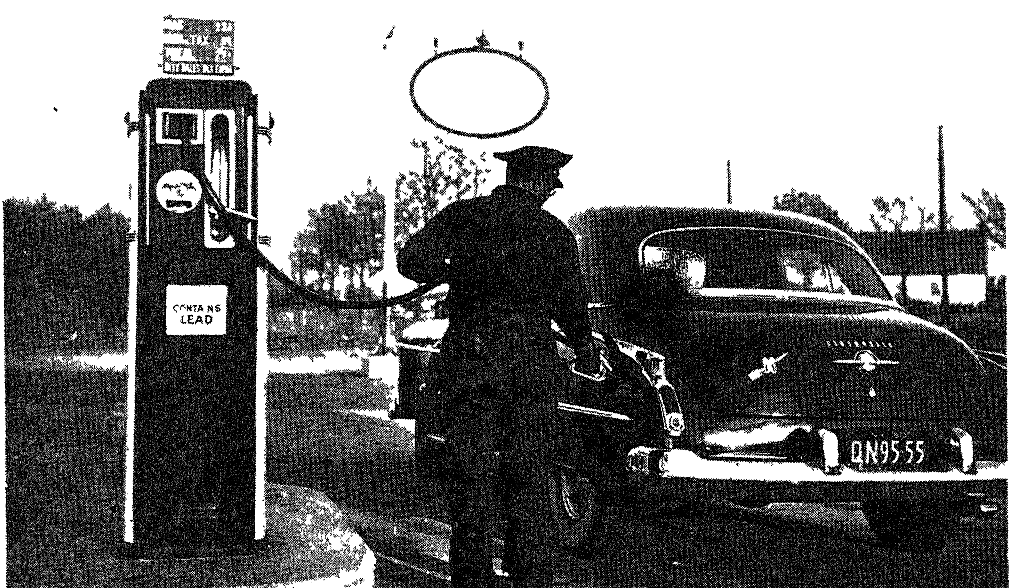
Table 1. Rate of Energy Transformation by the Body in Different Kinds of Muscular Exercise

Type of Exercise	*Rate in Mets* *	*Type of Exercise*	*Rate in Mets*
Resting, or basal	1.0	Fast walking (4 miles per hour)	4
Sleeping	0.8	Mining coal	4
Standing quietly	1.2	Sawing wood	5
Dressing and undressing	1.4	Skiing	6 to 10
Dishwashing	1.6	Running (5½ miles per hour)	7
Slow walking (2 miles per hour)	2	Long-distance running	10 to 12
Cycling	3 to 7	100-yard dash in 10 seconds	100
Rowing	3 to 10		

* A Met represents the resting, or basal, rate of energy transformation of an average man. The word comes from metabolism. It is about equal to the rate of energy used in a 100 watt electric bulb.

The figures in this table are only roughly accurate, since the actual rate of energy transformation will depend on the strenuousness with which a given activity is carried out. The energy required to perform a task is much greater if it is done rapidly than if it is done slowly. Friction has to be overcome in the different muscles that are involved; the higher the speed of movement, the greater the forces of friction. This is true also of mechanisms like automobiles. You use up more gasoline when you drive your car a distance of 5 miles at 50 miles per hour than when you drive the same distance at 30 miles per hour.

Naturally, more food will be required as the rate of energy transformation increases. A modest amount of food will suffice for an invalid resting quietly in bed all day long A miner will have to eat much more if he is to do his job effectively Athletes must also be well fed. Many American colleges and universities have a special training table where football players eat carefully selected food in adequate



Standard Oil Co. (N. J.)

The fuel that is being pumped into this car will be burned in the cylinders, thus releasing energy.

quantities. As a result, the coach can feel reasonably certain that his charges will have enough energy for their violent play.

What happens in the body during exercise?

When you step on the accelerator of your car, the carburetor feeds more gasoline to the engine. The engine runs faster — that is, the chemical energy of the fuel is changed into heat energy and mechanical energy at an increased rate. But it is not enough to supply the engine with more gasoline; if that were all, your car would soon be on the scrap heap. A great many other factors are involved.

In order to burn the fuel, a greater supply of oxygen is needed; hence, the carburetor must suck in air to the engine in greater quantities than before. A good deal more heat is generated at high speeds. To keep the engine from becoming overheated, more cooling must be provided by the water pump, which circulates water through the engine jacket, and by the fan, which blows air over the radiator. The ignition must produce more sparks per minute to fire the fuel in the cylinders; more oil must flow in order to lubricate the working parts. Many operations are required, therefore, in order to bring about an increased rate of energy transformation in your automobile.

So it is with the human body when it passes from rest to exercise The muscles must transform chemical energy into mechanical energy at a faster rate than before, but a good many other things must happen, too.

To burn more fuel, the muscles need a greater supply of the oxygen that is carried to them by the circulation of the blood Therefore, the flow of blood to the muscles must increase greatly. To charge the increased blood flow with sufficient oxygen, the lungs must pump more air. Notice that your breathing becomes deeper and faster the minute you start exercising.

As the muscles become more active, more chemical energy is transformed into heat energy. This extra heat would quickly raise the body temperature to fever pitch if effective cooling were not provided.

The increased circulation of blood to the surface of the body — that is, the skin — helps to carry the heat away faster than normally. The sweat glands all over the body surface burst into activity and drench the body with perspiration; as the sweat

Standard Oil Co (N. J.)

The food that we eat is a fuel, like gasoline; it will release energy when it is burned in the body.

Wide World

In this 50-meter run, much of the energy of the racers comes from accumulating a big oxygen debt.

evaporates, the body loses heat to its surroundings. These cooling devices are quite effective, but they do not suffice if a person engages in particularly strenuous activity. The body temperature of the most perfectly trained athlete is bound to rise if he runs a mile race, or plays several fast sets of tennis or boxes ten rounds.

The increase in oxygen supply required for muscular exertion

The human mechanisms that take part in exercise are linked up by the action of the nervous system, which governs the action and the co-operation of all the parts of the body in muscular exercise. We still do not fully understand just what is involved. For example, what brings about the increase in the oxygen supply that is required for muscular exertion? We know that the rate and depth of breathing are controlled by the amount of carbon dioxide in the blood, but this is by no means the whole story. Nerve impulses from the muscles to the brain undoubtedly play a part. It is probable, too, that when the motor cortex — the part of the brain that controls the activity of the muscles — goes into action, it sends nerve messages to the various muscles that control breathing.

In exercising, we "live on income" or "go into debt"

In exercise, as we have seen, the supply of oxygen to the muscles increases as they become more and more active. There is a limit, however, to the rate at which the lungs can breathe air and the heart can pump blood. The maximum rate for each individual depends on his fitness and his training for a particular form of exercise.

Professor Archibald V. Hill, of England, a Nobel Prize winner in physiology, measured the rate at which a group of athletes breathed in air and absorbed oxygen. He found that an athlete of average size, at rest, uses nearly half a pint of oxygen each minute; when doing violent exercise, he can take in roughly 15 times as much oxygen, or more than 7 pints a minute. This would correspond to 15 Met units in Table 1. Yet how can we say that 15 Mets is the maximum rate for taking in and using oxygen, when the table shows that a sprinter in the 100-yard dash transforms energy at the rate of 100 Mets?

Here our comparison of the human body with the engine of an automobile breaks down. The car engine can only "live on its income"; it can burn only as much gasoline as the fuel pump supplies, together with as much oxygen as the carburetor can draw in. This, of course, sets a definite limit to the speed of a car. If it has a maximum speed of 100 miles per hour on a certain track, it cannot go faster than this, even for a very short time. The maximum speed for a 1-mile race will be the same as for a 10-mile race; it will be 100 miles per hour.

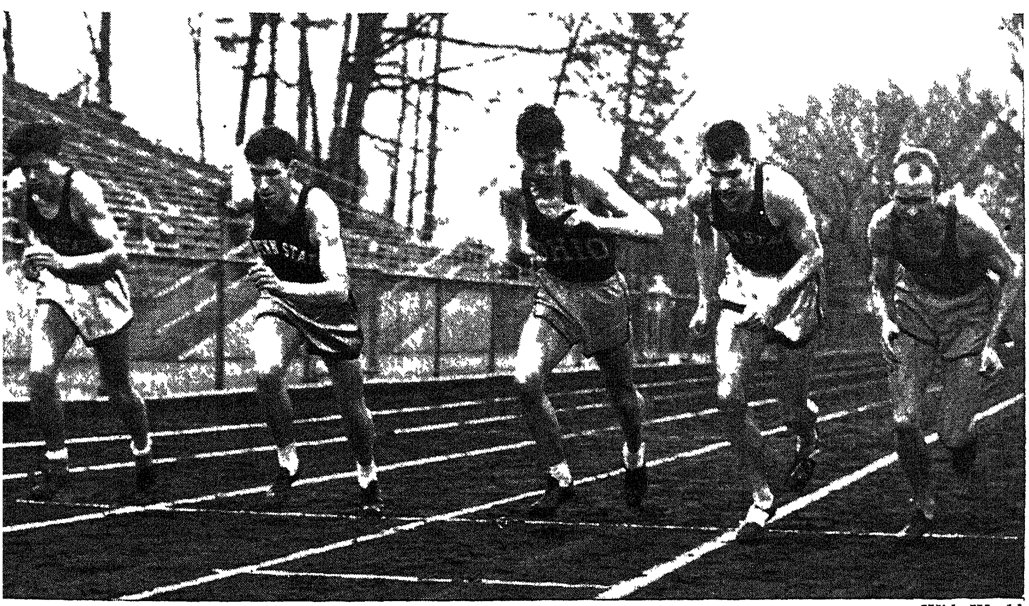
This is not true in the case of the human machine. The average speed of a sprinter in a 100-yard dash is not the same as that of a miler or a ten-mile runner, as a glance at the following table will show. In it we have given the world's running records in hours, minutes and seconds; in each case we have also calculated the average speed in terms of miles per hour.

Table 2. World Running Records Recognized by the International Amateur Athletic Federation, April 1951

Distance	*Record Time* *Hrs.*	*Min*	*Sec.*	*Average Speed in Miles per Hour*	*Record Holder*	*Date*
100 yards			9.3	20 4 [25 for last 50 yards]	M. E. Patton, U.S.A.	1948
220 yards			20.2	22.1	M. E. Patton, U.S.A.	1949
440 yards			46.0	19.4	H. McKenley, Jamaica, Brit. W. I.	1948
880 yards		1	49.2	17.8	S. C. Wooderson, Gr. Brit.	1938
					M Whitfield, U.S.A.	1950
1 mile		4	1.4	14.9	G. Haegg, Sweden	1945
2 miles		8	42.8	13.8	G Haegg, Sweden	1944
3 miles		13	32.4	13.3	G Haegg, Sweden	1942
6 miles		28	30.8	12.6	V. Heino, Finland	1949
10 miles		49	22.2	12 1	V. Heino, Finland	1946
15 miles	1	17	28 6	11.3	M. Hietanen, Finland	1948

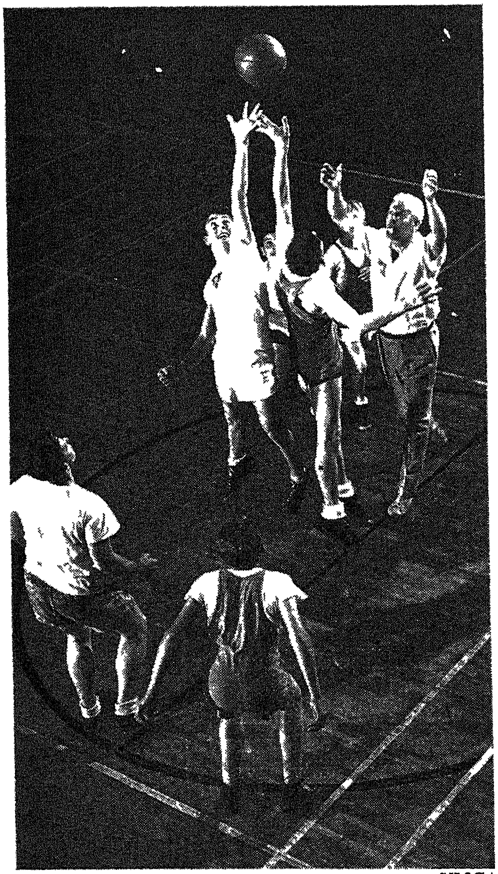
The table shows that the shorter the distance the greater the average speed that a human can attain. There is an apparent exception in the case of the 100-yard dash, since the average speed here is lower than that for the 220-yard run. But this is not really an exception; the comparatively low average speed for the 100-yard dash is due to the fact that the time lost in getting up speed counts for much more in a short race than it does in a longer one. Actually, the speed recorded in the last 50 yards of the 100-yard dash is close to 25 miles per hour, the figure in brackets in Table 2.

For distances longer than a mile, the speed does not decrease greatly. The rate of energy transformation of the long-distance runner turns out to be close to fifteen Mets; it corresponds to the maximum rate at which the body can take in oxygen.



Wide World

In this long-distance race, there is a fairly steady balance between energy output and oxygen intake.



YMCA

In this basketball game, the players are piling up tremendous oxygen debts, which must be paid later.

Evidently, in the case of sprinters, the muscles can transform energy at a much greater rate than this. In other words, the muscles are not limited, as is the automobile engine, to living on income, but for a short time at least they can pile up an "oxygen debt." That is, they can transform chemical energy into mechanical energy and heat energy without any reaction with oxygen. They can do this by breaking down the glycogen, or animal starch, stored up in the muscles and liver, to form lactic acid — a reaction that does not require oxygen.

Extra oxygen will have to be taken in later to pay back this oxygen debt when the heavy exercise is over. This extra oxygen will then react with the lactic acid that has accumulated in the muscles. Part of the lactic acid will be reconverted into glycogen, which will be stored anew in the muscles and liver; part of it will yield carbon dioxide and water, which will be passed out of the body with other waste products.

The total oxygen debt that can be accumulated is strictly limited. It is about twenty-nine pints of oxygen for a trained athlete. When he has piled up the maximum oxygen debt, the store of glycogen in his muscles has been practically used up and excessive quantities of lactic acid have accumulated. His muscles are now completely exhausted, and his legs will buckle under him.

In the 100-yard dash, much of the energy comes from piling up an oxygen debt, since a good sprinter does not take a single breath from start to finish. In contrast, in long-distance runs, there is a more or less steady balance between the output of energy and the intake of oxygen; the runner accumulates an oxygen debt only in the final sprint for the tape. When a new record is established, it is often because the winner has found a better method — for him, that is — of spending both his income of oxygen and his borrowed oxygen, so that he arrives almost completely "bankrupt" at the tape.

Look at Table 2 again. You will note that almost all the records for distances up to one mile are held by Americans, but records for longer distances are all held by Europeans. This has been more or less true for years. Apparently, while other races excel at "running on income," Americans excel at bursts of activity, piling up tremendous oxygen debts that have to be paid later. Consider the all-out spurts and big oxygen debts in America's favorite autumn sport — football. If it were not for the interval between halves, more or less frequent time-outs, wholesale substitutions, the marking off of penalties and the like, the players would be in a state of complete collapse at the end of a game.

The recovery period — paying back the debt

When you stop doing a violent exercise, your body does not return at once to its normal state. For quite a while you will breathe fast and deeply, your heart will

pound and your skin will perspire. In fact, you will not feel up to par again until practically all the oxygen debt has been paid. The period during which this debt is made good is called the recovery period.

The longer the heavy exercise has continued and the more violent it has been, the bigger the oxygen debt that you must pay and the longer the recovery period will last. Physical fitness and training are exceedingly important in this connection. The fit person will have less oxygen debt to pay, because he has been more efficient in producing mechanical energy; he will also require less time to pay the debt in the recovery period.

Professor Hill measured, in three different men, the time required to recover from the effects of marking time at the double-quick. For a man of 35, it took 20 minutes for full recovery; for a 24-year-old student, it took 12 minutes; for a very fit young student, who was a champion swimmer, only 8 minutes.

After violent exercise that lasts longer, it may be an hour or more before the body is back to its normal resting state. In our laboratory, we once recorded the heartbeat of a student lying on a bed; we were puzzled to find that for nearly an hour it kept getting steadily slower. The mystery was solved when we found that he had just played in a basketball game and that he was not very fit.

The body must make up its "water debt"

During the recovery period following heavy exercise, you will note that you become very thirsty. The body is serving notice in this way that it has lost a great deal of water in perspiration during the exercise and that this "water debt" must be made up. The total weight of water lost in this way may amount to several pounds.

In long-continued heavy work, especially in hot surroundings, it is a good idea to drink not pure water but water with salt added (a teaspoonful to a gallon). The reason is that, together with water, the body has lost a considerable amount of salt as a result of perspiring freely.

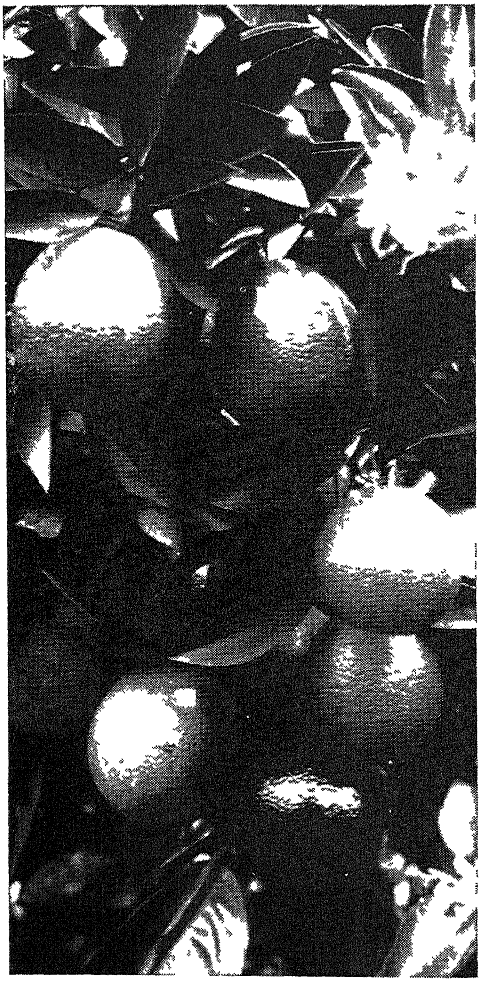
There does not seem to be any salt-craving sensation in the human body, corresponding to the water-craving sensation, or thirst. This deficiency is really most unfortunate, since it may cause trouble. For example, for many centuries miners used to suffer from severe cramps in the muscles (miners' cramps). Then it was discovered that they simply needed salt to make up for the salt that they had lost in sweat; salt was supplied and this particular ailment practically disappeared. Curiously enough, animals seem to realize when they require salt. Deer or cattle will travel miles in search of it, and they will gather eagerly at the salt licks in our reservations.

In very violent exercise, though the oxygen debt may be paid back in an hour or so, the muscles may not fully recover for days. The body may be stiff and sore, blisters may form and there may be other distressing symptoms. All this indicates that the exercise in question is altogether too violent for the sufferer, at least in his present state of training.

The restorative effect of sleep

It has long been considered that the activity of the muscles and the brain and nervous system throughout the day results in the gradual accumulation, in the body, of chemicals that have something to do with tiredness, or fatigue. We do not know just what these chemicals are, although much research has been done trying to find them in the blood. The removal of these products of fatigue is probably very slow and not complete in the usual recovery period we have discussed. It is thought that only after a good night's sleep is the body really back to normal and ready for another day's exercise and work.

In sleep, the muscles are probably more relaxed than at any other time, except when the body is under the influence of a total anesthetic. The rate of metabolism is reduced up to 20 per cent below the basal, or resting, level. When we awake at last, renewed and refreshed, our muscles are ready for any demands that we may make upon them in the course of the day.



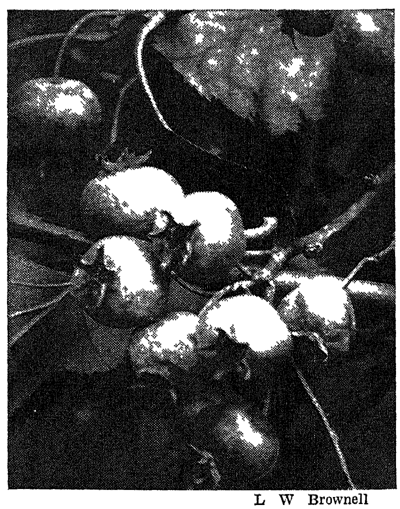
The orange is a fleshy true fruit.

L W Brownell

Aggregate fruit of the white mulberry.

FRUITS OF VARIOUS KINDS

The common belief is that fruits are the edible, sweet, more or less succulent products of plants. Actually, however, a fruit is any kind of mature, or ripened, plant ovary within which seeds develop.



L W Brownell

Accessory fruit of pear hawthorn.

Fruit of the wild black raspberry.

L. W Brownell

THE FRUIT OF PLANTS

The Several Characteristics, Repellent and Attractive, That Fruits Assume to Perpetuate Their Species

THE INCREASED POPULARITY OF FRUITS

WE have now to enter upon the consideration of the last aspect of the individual life of a plant which will come under our notice in these pages. We have still to pay some attention to the societies of plants as found in trees and forests, but in this chapter we shall conclude our study of the physiology of individual plant life with a brief survey of the final product of that life — namely, the fruit.

Let us, first of all, be quite clear as to the meaning of the word itself. What is "a fruit"? The answer depends upon the sense in which the term is used and by whom the question is put. In the popular sense, a fruit is generally understood to be some product of a plant of a more or less succulent nature, which is more or less delicious as food, and, as a rule, forms a covering inclosing seeds. This meaning would include such plant products as apples, oranges, peaches, pears, lemons, cherries, grapes and a host of others of a similar nature. In a somewhat more limited sense, however, a fruit means the reproductive product of a tree or any other plant — that is to say, the seed of the plant or any product of a plant which contains the seed. In this sense the word covers such products of plant life as wheat, oats, quinces, acorns, melons, as well as those in the former list.

Even botanists use the word to convey slightly different significations, but in the science of botany the fruit is usually taken to mean the ripened ovary or ovaries and the parts organically connected thereto. It is frequently composed of essentially two portions — namely, the seed itself, and the covering around it, or pericarp In the broadest botanical sense, the fruit should mean everything destined to undergo alteration as the result of the process of fertilization in the flower or any part of the flowering axis. If one remembers that all these changes are for the object of producing an embryo, and preparing it to live a separate life from the parent plant, it is obvious that everything included in the structures helping to this end will constitute a portion of the fruit. Looked at in this way, the seed-case, seed-capsule, or pericarp, as it is variously termed, is only a part of the fruit, though in many cases it constitutes nearly all that there is of it, and, as will be seen, is frequently described as the fruit seed. Having thus cleared the ground so as to understand in what various ways the term is used, we may now pass on to know some of the most common types of fruits produced by plants.

We may first note the fruits derived from the pistil only, in which case they are called "non-accessory" fruits while those which develop from the pistil or pistils plus some extra organically connected part like the calyx or receptacle are called "accessory" fruits. In those plants in which the seed-capsule, or pericarp, grows into a succulent, fleshy mass, the resulting mass of fruit is what we commonly call a "berry". This may be either accessory or non-accessory. Those of the orange, deadly nightshade, barberry and the grape are non-accessory in position, while the berries of the mistletoe and the gooseberry are accessory.

A second type of fruit is that to which we usually refer as "stone fruit" or "drupe". In this case it is the outer portion only of the seed-capsule, or pericarp, which has become the succulent, fleshy, and often edible mass, and the inner portion is, as the term implies, of a stony character. Within this stone lies the true seed. Most of these stone fruits, or drupes, will be found to contain one single seed in each stone, as does the cherry. There are some, however, which contain two stones, each inclosing a seed, like the buckthorn; and some even, like the raspberry or blackberry, which contain many stones, each with its seed within. In sharp distinction to these soft, succulent types we come to those fruits usually termed "dry". In reality it is the seed-capsule, or pericarp, which is *dry* in this type, the seeds being dry usually in fleshy and dry fruits alike. The group is further subdivided into "indehiscent fruits", and "dehiscent fruits". In these groups we have a number of edible products familiar to everyone. The indehiscent dry fruit separates from the plant with the seed inside it, and the whole product may be so adapted as to aid in the dispersal of the seed inside, and to protect the embryo. Of such character are the nuts, which arise from pistils made up of more than a single carpel, as in the beechnut. Other indehiscent fruits are produced from a pistil made from one carpel only, then termed "achenes", as is the wheat and strawberry. Most nuts contain only one seed, even though they arise from an ovary with several chambers, and this is because during the development in the later stages all the chambers except one disappear. That one contains the ripe seed.

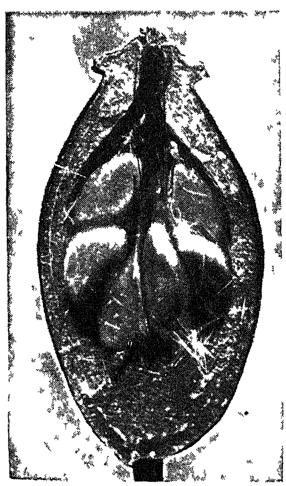
FLOWERS OF THE MAPLE DEVELOPING INTO FRUITS

In the flowers to the right the pistil has not developed, but in those to the left, which are older, the growth of the wings is clearly seen These are indehiscent dry fruits known as "key fruits" or "samaras".

The next group of dry fruits is that of the schizocarp, which is really made up of a number of achenes joined together. In this type are included such fruits as the marrow, the caraway and parsley.

Thirdly, we have the "dry dehiscent" fruits, some of which are spoken of as "capsules". The pericarp, when it is quite ripe, splits and distributes the seed in a number of processes, some of which we studied in connection with plant dispersal. Here, after the liberation of the seed, the pericarp, or seed capsule, generally remains behind, still attached to the plant. If not, it separates from the parent in pieces — that is to say, it *dehisces;* hence the name. But, whichever method is adopted, this dry pericarp has nothing further to do with the growth of the seed which has been set free from it, in contrast with that of the nuts, for example, where it has a protective function lasting for a long time.

AN IVORY NUT

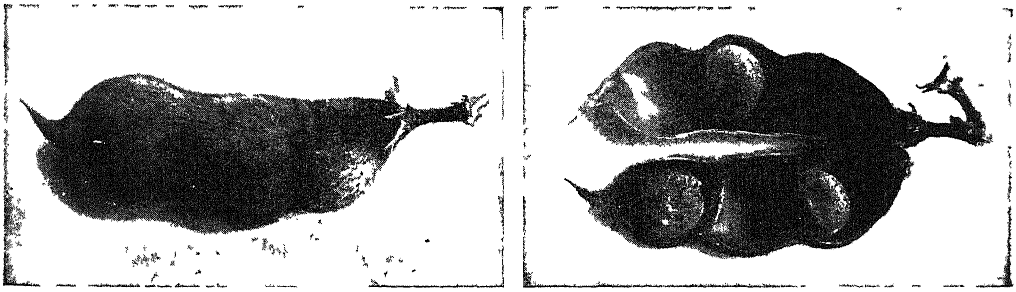


A WILD-ROSE HIP

Both these photographs show longitudinal sections with the seeds inside.

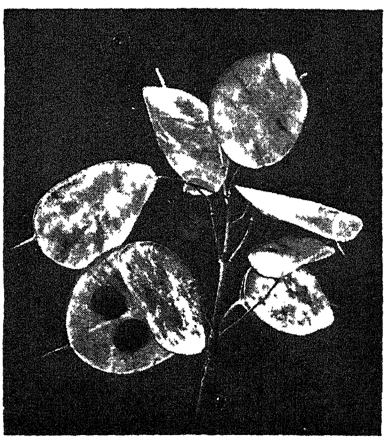
Regarding the word "fruit" in the botanical sense, these dry dehiscent fruits, or capsules, are the most common fruits of all. One of the best-known examples of them is the follicle, which opens along one side, as in the milkweed. Another common kind is the legume, or pod, which, when ripe, splits along both sutures into two valves, as in the pea and the bean. Still other dry dehiscent fruits might be regarded as being more truly capsules — for instance, those of the poppy and the violet and the snapdragon. Still another kind of dry dehiscent fruit is that which is characteristic of the well-known "honesty", in which the walls of the carpels gradually disappear and leave a very curious appearance of a delicate framework with the seeds still sticking to it. So much for the dry dehiscent fruits.

THE FRUIT OF THE MALLOW



LUPIN PODS CLOSED, SHOWING PROTECTIVE HAIRS, AND OPEN, SHOWING SEEDS WITHIN

Next we may note the type of fruit termed a "collective" or "multiple" fruit, produced by some of the plants in which the flowering portions grow in very close clusters, and, as the result, when the fruit is developed they are produced so close together that they fuse more or less completely into one mass. Since this really contains a number of fruits, the term "multiple" or "collective" fruit is applied to the whole thing. They are usually supported on one fleshy framework of a succulent nature. Well-known cases of this kind are those of the mulberry, the bread-fruit and the pineapple.

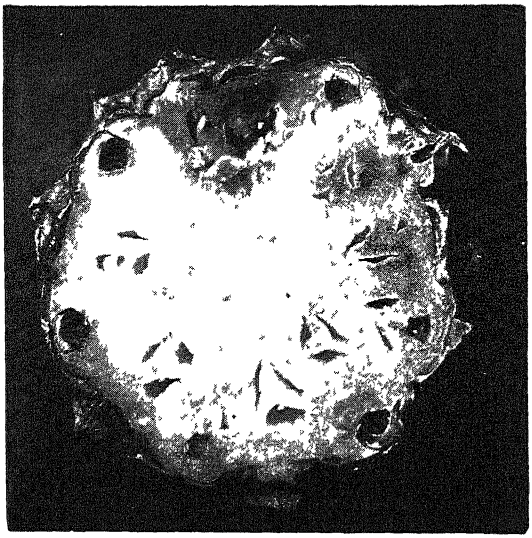


HONESTY SEEDS WITHIN THE FRUITS

Another kind of fruit cluster is that seen in the raspberry and many other plants, in which, however, the fruit is really better described as an aggregate fruit, because produced from many pistils in a single flower while simple fruits arise from but a single pistil in a flower. So far, in our consideration of types of fruits, we have referred only to the class of plants known as "angiosperms", or those plants which have their seeds inclosed in some kind of vessel. In that group of plants whose seeds have no seed-vessel in connection with them, which are termed "gymnosperms", and of which all the coniferous plants are examples, the process of development has some peculiarities of its own which we need not enter into here, beyond stating the one fact, that, although many embryos are produced at the earliest stages, only one of them reaches maturity, and this one, of course, is found in the ripe seed. This is the case in the silver fir, spruce fir and pine. From the species just mentioned, it will be noticed

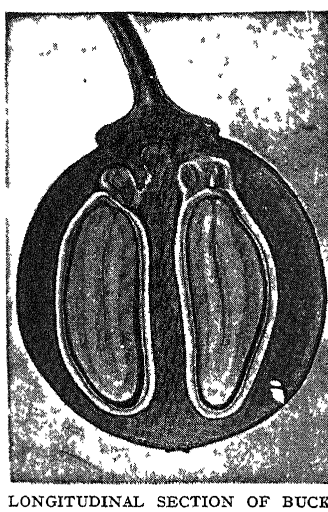
that many of these gymnosperms produce cones, the cone being really a mass of scales that may be regarded as the aggregate fruit. In fact, the gymnosperm plants produce their fruit in many ways; but all of them have this in common — that the embryo is an extremely hardy one, and is provided by the parent plant in the aggregate fruit with many protective appliances, some of which are also obviously intended to aid in dispersal, and that the seeds are not borne in a closed ovary.

The fruit needs protection at two stages of its career. In the first place, it must be protected from destruction by animals and by severe climatic conditions while it still remains attached to the parent plant. Some of these protective arrangements we have already studied in connection with stems and leaves, and it is interesting to note here that similar special developments occur in connection with the fruit. Just as in the case of the leaf, so here we find surrounding the fruit such structures as thorns and prickles of different kinds, excellently adapted for this purpose. The capsule of the thorn-apple takes its name in this way. Some of the pines have the scales of their cones terminating in very sharp spines. A peculiar protective arrangement is that in some of the mimosas, where the pods are so crowded together that they form a double row of spines. All these protections apply only until the time that the seed is fully ripened. After that time, when the fruit breaks up into its different parts, they no longer give protection, but they may still aid as a means of dispersal. In other cases it would be a distinct disadvantage to the seed to be so protected afterwards — for example, in those which depend upon the agency of birds for their dispersal. In this case the former protective organs are generally separated from the seed when ripe, or else the fruit itself, as we studied in a previous chapter, is of a succulent nature externally.



TRANSVERSE SECTION OF A PINEAPPLE
The fruits are supported on the fleshy framework here shown

An interesting kind of fruit is that seen in the rose, where it is known as a "hip". This fruit, it will be remembered, remains attached to the rose-tree, or plant, even after it is ripe. Within it, of course, are contained a number of small, hard fruits, like diminutive nuts. Their covering, however, forms an attractive food to various kinds of birds, especially blackbirds; and in eating this they also devour the seeds themselves, which remain undamaged, and so pass out with the droppings of the birds in various places. Curiously enough, the rose plant, and others of its type, are afforded protection from mice and other creatures which would destroy the whole fruit by gnawing it, by sharp prickles on their stems or branches; and the fruit of the blackberry and the raspberry has the same protection.



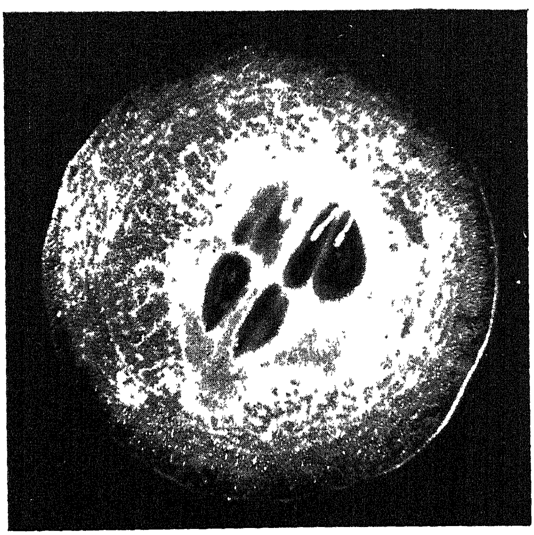
LONGITUDINAL SECTION OF BUCKTHORN FRUIT

One would not think at first sight the pod of such a plant as the pea was very well protected, and possibly in some respects it is not. A second thought, however, will show us that the long, delicate

stalk which bears the pod is in itself a protection, because it makes the fruit rather more difficult of access. The seeds, in this case, are so very nutritious, and hence so much sought after, that they would have little chance of escape were it not for this device. The same thing applies to the long stalk of a cherry with its fruit at the end. This stalk does undoubtedly offer considerable difficulty to the attacks of insects and other enemies, as may be gathered from the manner in which the cherry is devoured should it happen to fall to the ground.

FURZE PODS ON A SPINY BRANCH

One other means of protection against the ravages of animals must be mentioned. Although the fruits themselves, or parts of them, afford delicious food material for animals, it is, nevertheless, true that the edible portion of the fruit is not attractive or palatable until the seeds are ripe, when, of course, they can be separated from the other parent structure without risk. This is excellently seen in such fruits as the grape, the cherry, the orange, the plum and so forth. As long as the covering of these seeds is bitter, the seeds themselves are adequately protected. Later on, when the succulent portion has become sweet and nutritious, the contained seeds have reached ripeness, and are ready for distribution by animals. Perhaps the best example of all of such a case is that of the walnut, in which the seed itself, which is, of course, within the nut, is surrounded by an extremely disagreeably tasting covering, that, as far as we are aware, offers no attractions at that stage to any animal.

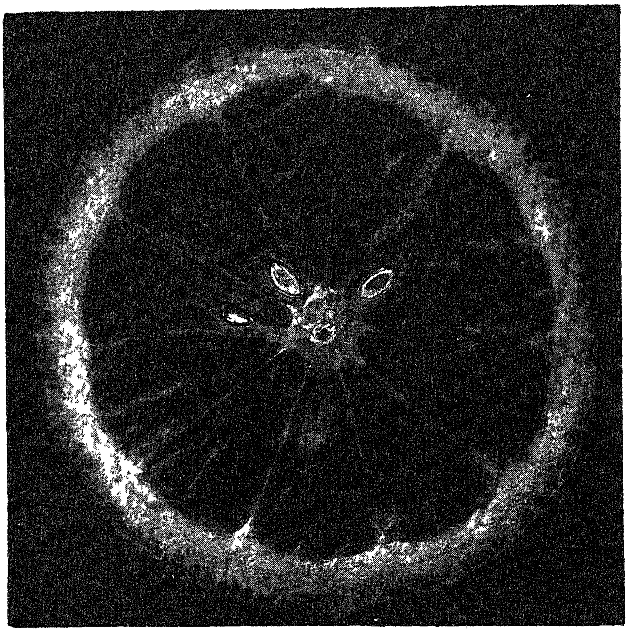


SECTION OF A CUCUMBER, SHOWING SEEDS ATTACHED TO ITS INTERNAL WALLS

In still other cases protection is afforded to the fruit by various substances of a sticky, strong-smelling or resinous nature, rather characteristic of the pines. It is this material which sticks so pertinaciously to a knife if an attempt be made to cut across the young cone. It is only when the cone is ripe that birds can gain access to the seeds that then are ready to be dispersed. The seeds of pines are, of course, commonly dispersed by the wind rather than by birds Many plants produce some sticky material of this kind in one or other of their structures. In the common hop there are glands on the scales which do the same thing, and the same is true of the hemp. In neither of these plants is the fruit interfered with until ripe, even by sparrows.

Next, as to the protection of the fruit against climatic agencies. The two things to be most dreaded are too much moisture or too little. Seeds contained in the berries and stones are not so much exposed to these factors But in those fruits of the dehiscent type, which open before the seeds are scattered, protective arrangements against rain gaining access to the fruit are found. In a great many cases it is found that these capsules, or valves, open only when the weather is dry, closing up when the atmosphere becomes moist.

This protection to dry dehiscent fruits only exists as long as the fruit remains on the parent plant, but in the nuts it persists, of course, for very much longer. Here the seed-covering and the seed go together for, it may be, a very long period, the shell of the nut protecting its kernel all the time, and in some cases even assisting it to germinate.



TRANSVERSE SECTION OF A LEMON

Lastly, in this connection, it may be interesting to note the extraordinary variation in size of the portion of the fruit which surrounds the embryo at the time when it is separated from the parent plant. "The seed of the terrestrial orchid *Gymnadenia conopsea* is one millimeter in length, and weighs .008 gram; that of the cocoanut palm, 11–14 cm., and weighs 800–1100 grams. The wind bent-grass (*Apera spica-venti*) has a grain 1.2 mm. long, .3 mm. broad, and weighs .05 gram; the fruit of the Seychelles palm (*Lodoicea sechellarum*) measures 32 cm. by 18–25 cm. by 22 cm., and weighs 4200–4800 grams. The largest fruits are produced by the *Cucurbitaceæ* In a suitable soil gourds attain a diameter of half a meter, whilst fruits of the melon-pumpkin (*Cucurbita maxima*) have a greatest diameter of over a meter, and weight of 75–100 kilograms. The fruits of the bottle-gourd (*lagenaria*) attain, under favorable circumstances, a diameter of 30 cm., and a length of a meter and a half."

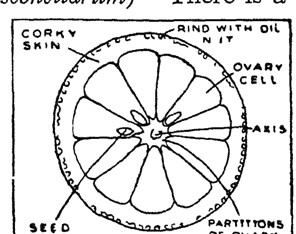


DIAGRAM OF TRANSVERSE SECTION OF A LEMON

Let us now very briefly study the structure of a few typical fruits, selecting our examples from those in common use in our households, and of value from a dietetic point of view, in order that we may apply what we have learned in this and previous chapters in a practical manner. Let the reader procure for himself, or herself, a lemon, selecting as large a one as is obtainable, and proceed to note as many as possible of the following points. At the base of the fruit there will be observed the remains of the calyx. Since the lemon itself is the ripened ovary, you might expect to and do find at the end opposite the calyx the region once occupied by the style and stigma. The external rind is seen to have a pitted surface, the significance of which has been explained With a knife now make a transverse section of a whole lemon towards the end of the fruit where the stigma was. Such a section will enable one to observe quite a number of points, among which are the following — There is a somewhat thick skin, of a pale yellow or lemon color externally, but quite white on the inside. The whole fruit itself is divided into a number of parts, in the shape of wedges, often termed "quarters" in this and the orange. These divisions are really the matured cells of the ovary. Each of them shows a thin skin which is the partition wall between the cells of the ovary. In the middle of the transverse section there is a white central column of a pithy texture. In one or other part of the section there will probably be seen some seeds inclosed in the fruit, whose position and method of fixation should be observed.

With a magnifying glass some further points of interest may be noticed, especially on the skin, or rind, where there are little round cavities which contain an oil — the oil of lemon. This is the substance to which the fruit owes its peculiar smell and taste, and which, if squirted out into the eye, makes itself painfully obvious. The magnifying glass will also show that the pulp of the lemon is made up of a number of tubes, and these tubes are full of juice. Right in the middle of the fruit on a transverse section will be seen dot-like structures, the cut ends of fibro-vascular bundles. It was along these, it will be remembered, that the sap of the plant was carried to the fruit-cells, enabling the latter to develop. A lemon is a berry, a non-accessory fruit, an indehiscent fruit and a simple fruit.

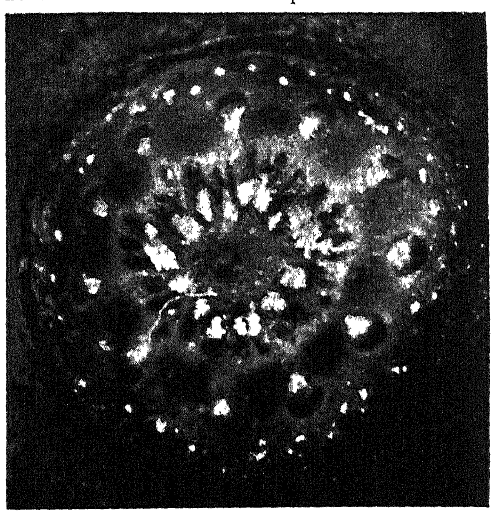
Next secure a specimen of the common tomato, selecting preferably a small one. This well-known edible fruit is a typical example of the grouping of berries. It will probably exhibit the persistent calyx, with its peduncle. The thick skin, or epidermis, can be readily peeled off, and the interior of the ovary seen, as well as the partitions between the cells of the latter. Within these the contents of each cell are obvious, and the attachment of the seeds to the placentæ can be easily seen. Each seed, it will be observed, has a distinctly slippery covering. A tomato is a berry, a non-accessory fruit, an indehiscent fruit and a simple fruit.

A common bean-pod, taken next, will serve excellently as a type of the fruit of legume. A single glance will show on it the stigma, the style, the ovary, the calyx, and the peduncle. Within it may be seen the seeds at their stages of development, each lying in its own receptacle, divided by a solid wall from the neighboring one The beans themselves are attached to the placenta by a stalk, with the function of which we are already familiar. If, instead of a young, fresh bean, an old, dry one from last year's crop be taken, the observer will notice where the splitting, or the dehiscence, of the pod took place. A bean is a legume, a non-accessory fruit, a dehiscent fruit and a simple fruit.

To study a common *achene*, all that is necessary is to examine with a magnifying glass the fruit of the common dock This, it will be found, is inclosed in three membranes, which are dried sepals It will

THE OIL-GLANDS OF ORANGE-PEEL
It is the bursting of these glands which produces the fine sprays of bitter oil when an orange is peeled

be further noticed that this is an example of a fruit that remains attached to the parent for some time after it is ripe. It is an achene, a non-accessory fruit, an indehiscent fruit and a simple fruit.

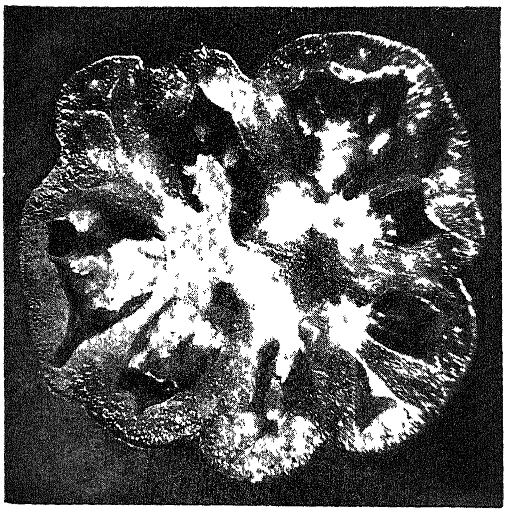


THE ROUND SCAR AT THE BASE OF AN ORANGE
This section is where the fruit is separated from the stalk, and shows the two rings of fibro-vascular bundles.

Next may be examined an ordinary apple or pear, which presents still further points of note. In this case the carpels arise in a whorl from the end of the axis, where there is an excavated receptacle. The

margins of the carpels fold inwards, and ultimately fuse together so as to form an ovary divided into a number of chambers, which is hence termed "multilocular". This ovary fills the entire cavity of the receptacle, and, as a matter of fact, is completely fused with the inner wall of that cavity. The ovules, or embryonic seeds, are carried on the infolded margins of each carpel — that is to say, on the walls of the several compartments of the multilocular ovary. The same arrangement is found in the now somewhat uncommon medlar. An apple is a pome, an accessory fruit, an indehiscent fruit and a simple fruit.

So much for a fruit looked at as a botanical product. In such space as remains to us we turn our attention to the subject of fruit as a whole, noting in connection therewith some points of interest.



TRANSVERSE SECTION OF TOMATO, SHOWING SEED-CHAMBERS AND PLACENTÆ

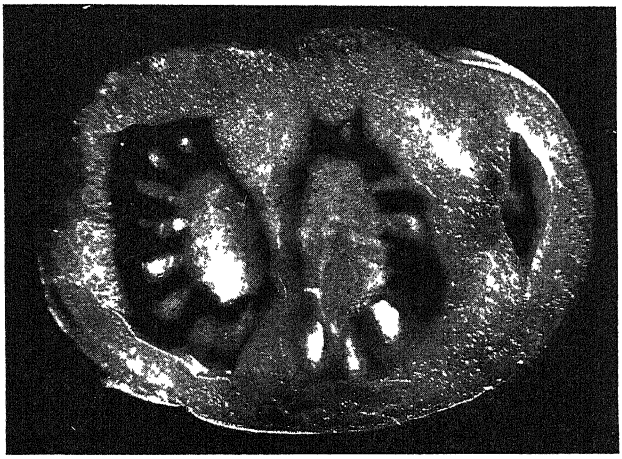
The dietetic value of fruit in the food of a nation has been greatly more appreciated in comparatively recent years than it was formerly, possibly because of the increased trading facilities which have resulted in placing enormous quantities of foreign-grown fruit upon the home market at prices that have brought it within the reach of practically everybody.

Still more noticeable, perhaps, is the manner in which certain fruits which cannot be grown to advantage in a given climate have in recent years taken a place as an almost indispensable article of diet in the food supply of all people in civilized countries. Probably some of the readers of these pages will recollect the time when the banana was a comparative rarity in our shops and an absentee from our streets Today it can be bought very reasonably anywhere and everywhere in this country, and the total consumption is an immensely vast one. Even the very poorest inhabitants have it brought to their own doors, and find in it a fruit which is at once nourishing, sustaining and cheap. No better example than this of the banana could be taken to illustrate the value of fruit in general as food, and we may therefore select it to note some special points. If you wish for exercise to classify a banana as you did the apple, dock and lemon you would say it is a berry, an accessory fruit (the peel being accessory), an indehiscent fruit and a simple fruit.

Among the chief sources of supply of the quantities of this fruit are Jamaica, other West Indian islands and parts of Central and South America. The cultivated plant itself, curiously enough, is without seeds, and the new plants are produced by the process of propagating cuttings. Two fruits are sold under the general term of banana — namely, the true banana and a variety which is the plantain. The banana-tree in Jamaica grows to a height of about 12 feet, being almost twice as high as that in the Canary Islands. The root-stems of the plant produce leaves whose petioles form a hollow stem and blade, which are 6 feet long, or more, spread out. The stems which carry the bunches of fruit shoot straight up from among the roots, and show amongst the leaves. As may be seen in any large fruit shop, the banana grows in huge clusters of fruit, any cluster of which may weigh as much as fifty pounds. The yellow appearance of the skin, as well as the black patches which are frequently present, is produced by the process of artificial ripening taking place between the time of the gathering of the fruit and its reaching our market. When gathered it is perfectly green.

It may be noted in passing that the banana group of plants, all of which are

naturally tropical, have irregular flowers, in which the inferior ovary is, as a rule, divided into three compartments. The group includes, besides the banana proper, the plantain, ginger and arrowroot, so that its importance from the food point of view is abundantly obvious. All such plants require high temperature in order to bring them to perfection. In all probability the yield of fruit per acre from a banana plantation is greater than that of any other plant used for the food of man; and since the expense of cultivation and labor in connection with its production is very slight, it is no wonder that with the increasing consumption at the present time large fortunes are being made in the industry. When it is remembered that the importation of the banana into the United States, England, Canada and other countries is immense, some idea may be gathered of the amount of fruit produced.



LONGITUDINAL SECTION OF TOMATO, SHOWING HOW THE SEEDS ARE ATTACHED TO THE PLACENTÆ

Another fruit in connection with which we may note a few points, and one that, like the banana, has rapidly increased in popularity and consumption in this country, is the date. It belongs to the order of the palms (*Palmaceæ*), an order that includes also the cocoanut-palm. In the plants of this group the leaves form a very characteristic large tuft at the end of a long, cylindrical stem Not more than three seeds are produced by a flower. The date-palm is the chief product of the oases of the African and other Old World deserts. The fruit is carried on bunches, which have a single stem with a number of slender twigs, to which the fruit is attached, and each bunch may consist of from ten to thirty pounds weight of fruit. The dates themselves do not all ripen on the same bunch at the same time, and for this reason the practice obtains, in the best varieties, of picking by hand those on the bunch that ripen first, and shipping them at once in order to obtain a higher price. When the majority of the fruit on the bunch has ripened, the whole bunch is cut off and hung up to ripen; and this it does in the course of a few weeks. One of the best varieties come from the Sahara Desert, being exported largely from Algiers. When properly packed the fruit will keep for years without deterioration.

In conclusion, we may note a few points in connection with that universally popular fruit the orange, which is not only important as an article of diet in the form of the fruit itself, but supplies such immense numbers for the manufacture of marmalade. Marmalade was originally made from the fruit of the quince, but is now manufactured from orange-pulp — or it should be. The best marmalade is made from the use of both bitter and sweet oranges, along with lemons. Both of these fruits come from the coast of the Mediterranean, China, the Azores, Mexico, Australia and California. The oranges are gathered before they are quite ripe, when they are fully formed and the greenish color is just turning into yellow. They are wrapped in paper and packed in boxes that admit plenty of air.

The trees themselves live to be over a hundred, during a large portion of which time they may bear some thousands of oranges annually. The prolificness of the finest trees is such that one fully matured tree may carry twelve thousand oranges in one year. They have a very similar distribution to that of the lemon tree, and cannot flourish in the presence of frost. The fresh fruit eaten in the United States comes chiefly from Florida and California.

Black Star

Snakes symbolize mystery and danger. Here man faces the cobra — held sacred by millions of Hindus.

THE MALIGNED SNAKE TRIBE

Inspirers of Terror in Man and Beast but Friends of Agriculture

MASTERS OF THE WORLD BUT FOR MAN

THE common noun "reptile" has become an adjective, employed to characterize the basest, most malignant and contemptible of qualities in humankind This is taking a very serious liberty with our elders. The history of these unloved creatures was engraved by the finger of Time itself upon strata whose age was one with that of the hills when man himself was yet to be, in a future then infinitely more remote than is his beginning from the present age

Never before or since has the earth seen such weird, fantastic terrors as roamed the world when, in the great age of reptiles, cold-blooded, egg-laying giants parted the four quarters of the globe between them. The mind grows dizzy as it tries to conjure up the scene presented to the view when the world was in her youth. The dramatis personæ are part and parcel today of the rocks which man hews to make him a dwelling-place; and as we disinter them from their stony matrix we try to set them up again, petrified ghosts from out a dead age, in the manner in which they bore themselves Some we set upon their mighty haunches, and some we represent as tiptoeing across a marshy world, like titanic culverts on colossal struts whose dry bones live. And the effect is that, as we learn more, we realize how little we really know. So we doubt.

We wonder today whether that fearsome diplodocus in our Natural History Museum ever had a prototype walking as that one is represented as walking. We ask ourselves whether, after all, the frightful original was not in the main aquatic; whether, upon coming to land, its enormous bulk did not cause those pillar-like limbs to straddle and to splay even as those of the noisome crocodile of today We know how they produced their young — that in some cases these reptiles produced their progeny alive, the egg having been hatched within the mother's body. We know that because fossil remains have been found with the unborn young still within the ribs of the dam. We know something of their internal organism, from the curious markings upon fossil dejecta, which, first worn as charms and ornaments by modern women before the true origin of coprolites was ascertained, return, after treatment by the chemist, to renew the earth from which it sprang millions and millions of years ago. We know that some of these reptiles swallowed stones to aid digestion, as birds swallow grit and small stones today, because such millstones within a reptile's body have been discovered under circumstances which admit of no doubt as to their origin.

All this, and more, we know, and some of the results of our knowledge are set out in the first chapter of this group, but there is more that we do not nor ever shall know. For Time has swept the originals, themselves and their type, into her charnel-house; and only four orders remain, numerous in genera and species, in place of the eleven into which we have been able to classify the original assemblage. Only these four linger today to contest the losing battle against man and the rest of the animal world. Two of those orders, the crocodiles, and the tortoises and turtles, have already been disposed of, in a previous chapter. Here we divide an order, and, separating the snakes from the lizards, address ourselves to the former.

Snakes and lizards belong to the same order; and, although there are no snakes which would be mistaken for lizards, there are lizards which the vast proportion of observers mistake for snakes. Even a hearty lover of animals shrinks, dubious and afraid, from a glass-snake, which, for all his marvelous mimicry of the snake, is the jolliest little lizard in the world. To shun the snake and the snake-like is natural, and the fear experienced by reasoning man in the presence of a snake is shared by our unreasoning cousins the apes. The attempt has been made to analyze the sense of terror which we thus experience. One authority thinks we inherit it, another terms it the dread of the unknown and unfamiliar, the mental attitude which sees a ghost in an unusual effect of moonlight, or makes a dog bark at his own shadow, or a horse shy at some strange object on the road. Be the origin what it may, the sense of horror inspired by the snake is real enough. A man in pursuit of water-birds in a South American swamp was suddenly brought face to face with a great female puma, which, in spite of all stories to the contrary of the friendliness of this animal towards man, instantly prepared to spring upon him. Without a tremor he aimed, fired, laid her dead at his feet, and went his way rejoicing. Next minute the same man, in forcing his way through the tangled undergrowth, nearly touched a snake coiled round a branch. "The effect was worse than an electric shock, and the perspiration rushed from every pore of my body as I sprang back in mortal terror, not knowing at the time that it was a harmless constrictor. The suffering of those few moments was greater than I could have experienced had the puma rent me to pieces. The nerves which enabled me to draw a steady sight upon that mass of muscular energy, prepared to launch itself with irresistible force upon me, were completely unstrung by the sight of a miserable reptile, whose back I could have broken with finger and thumb!"

Courtesy N Y Zoological Society, Photo Elwin R Sanborn

RATTLESNAKE HEAD SHOWING FANG DEVELOPMENT

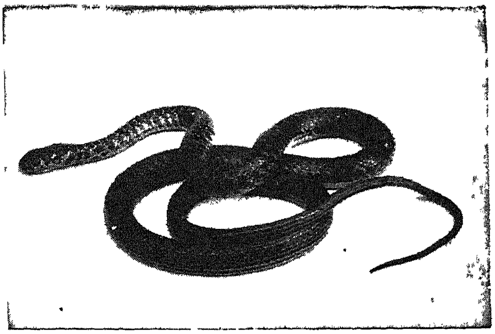
Some tissue has been removed from around the fangs to give a better idea of those members

Of course, this fear is not so blind and unreasoning in an educated man as it might be in an untutored savage, brought, for the first time in his life, into the presence of a serpent. The record of the snake is the worst of any living animal's, death-dealing insects alone excepted. We have no record of the deaths from snake bite in Africa, Australia and America, but in India every year from this cause over 20,000 deaths occur. In North America, where we have relatively few poisonous snakes to contend with, deaths from snake bites are very unusual. Our coral snakes, moccasins, copperheads and rattlesnakes seldom strike unless cornered or molested and one is always amply warned of the deadliest rattlesnakes by their habit of rattling the curious bell-shaped scales on the tips of their tails whenever alarmed.

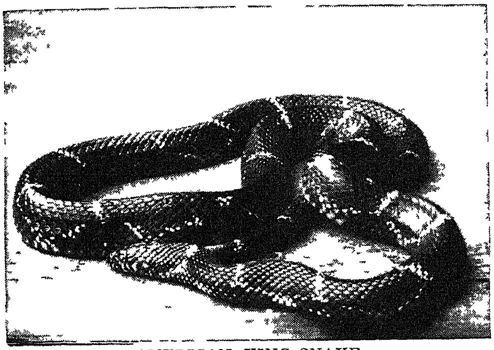
For every human life destroyed by a snake in India, five snakes are killed. Indeed, the total is far higher, for thousands

ANIMALS MOST DREADED BY MANKIND

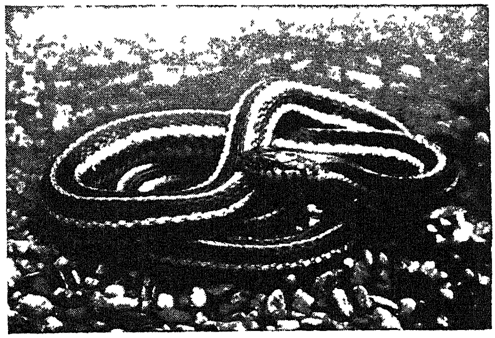
COMMON RATTLESNAKE



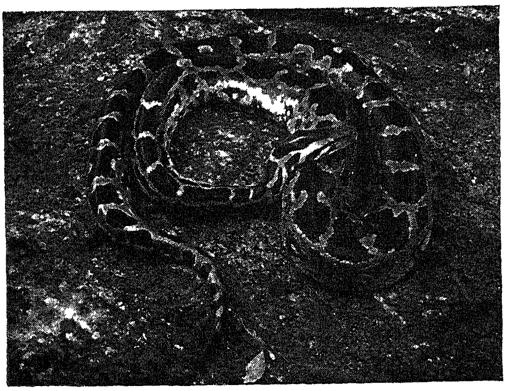
GARTER SNAKE



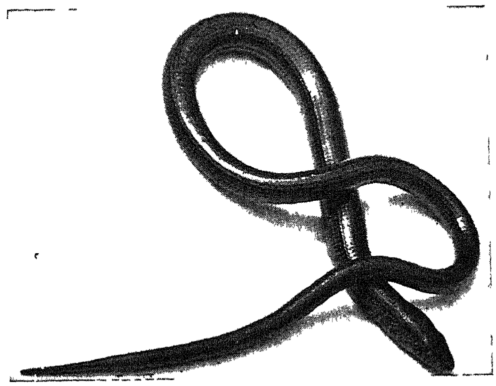
AMERICAN KING SNAKE



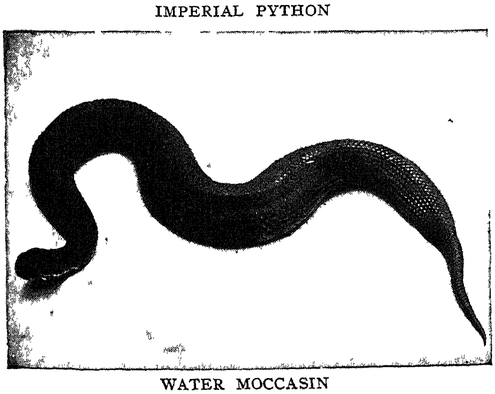
RIBBON SNAKE



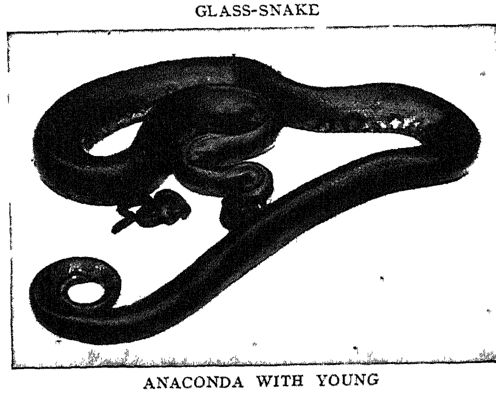
IMPERIAL PYTHON



GLASS-SNAKE



WATER MOCCASIN



ANACONDA WITH YOUNG

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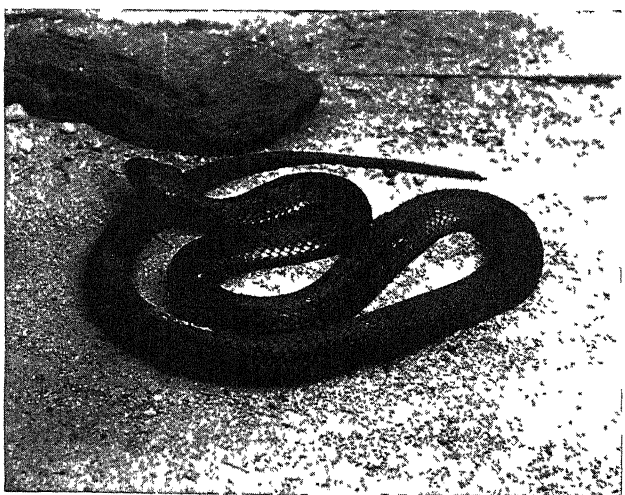
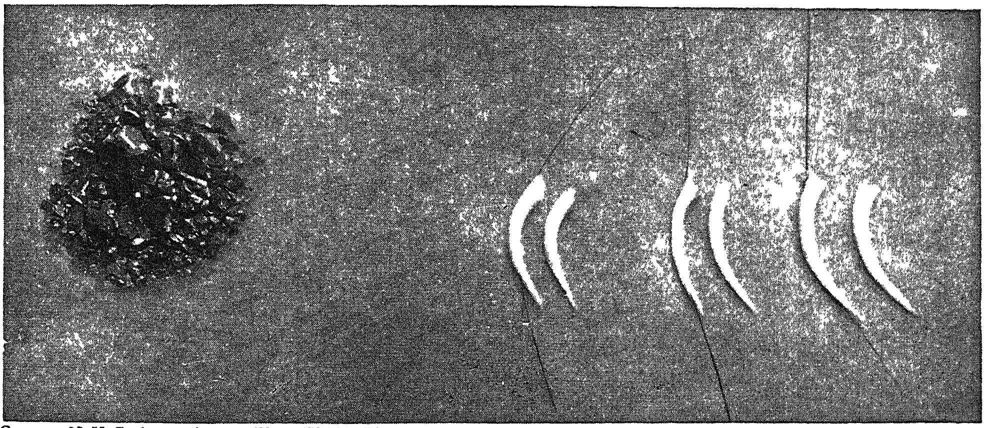
are destroyed by sportsmen and others, whose kills do not appear in the records of that department of the Indian government which awards payment for the destruction of the reptiles. Yet, in spite of all attempts to exterminate the pest, we find that late returns of fatalities are among the heaviest recorded.

It is conceivable that, were it not for the mastery of man, snakes might cover the earth; we might again have an age of reptiles. They have really very few enemies to fear. They possess weapons among the most formidable in the whole scale of animal nature. There is the poison of the venomous snake, capable of development on the side of virulence; there is the crushing power of the snakes which depend upon brute strength for the mastery of their prey. In saying that the virus of the snake is capable of still further lethal effect, we have this fact to go upon: that preying upon cold-blooded fish, whose organism is necessarily less sensitive than that of a warm-blooded mammal, the sea-snakes are armed with a venom fifty times as powerful as that of the dreaded cobra. The killing power of the venom possessed by land-snakes could be increased, and the size of these reptiles could be enhanced, so that the serpents would be capable of grappling with still larger prey than is at present the case. And, seeing to what prodigious power and measurements the anacondas, greatest of all the constrictor snakes, have attained, it is conceivable that the pythons and other crushing snakes, huge enough already, might render their bulk still more formidable. The only check upon this development would be that imposed by nature herself. The remorseless operation of the laws which swept away the giants from which our contemporary reptiles have sprung would, in course of time, reduce the snakes — bulk and brains do not keep company. But the extinction of an order is not soon effected. The snakes, small-brained though they be, are a very numerous assemblage — more than 1600 distinct species have, up to now, been classified, and additions are constantly being made to the list. Although they merely crawl and wriggle and writhe, they have brought their method of progression to such perfection that they seem not to miss the legs which they have sacrificed. Climate limits their range, and seas shut them in, but their distribution and diversity of habit are remarkable. There are snakes which haunt the jungle and the reed-bed, the river and lake and marsh, which lurk in caverns; bury themselves, all but the head, in sand; which burrow like worms; others which climb trees with inimitable facility, which swim like eels, while some make their home entirely in the sea. Except for the Arctic and Antarctic regions proper, snakes are pretty well everywhere, with the exception of Ireland and Iceland.


Courtesy N Y Zoological Society. Photo Elwin R Sanborn
ASP

For the man in the street the snakes fall into two divisions — snakes which are poisonous and snakes which are not. That is well enough so far as it goes, but we are not to understand that poisonous snakes form one related group, and non-poisonous snakes another. The fact is that the poisonous forms, together with certain non-poisonous groups, arise from a common stock. Every group of poisonous snakes has separately acquired its poison.

The mechanism of this poison apparatus is of interest. Let it be noted that snakes do not sting; to sting is the function of insects and jelly-fish. Snakes bite, whether poisonous or non-poisonous. The snakes which are non-poisonous possess four rows of teeth in the upper jaw; poisonous snakes frequently possess only two teeth in the upper jaw. Other teeth will be found in the upper jaw of the latter in all stages of development, but they are only "spares", as the motorist says. They are ready to take the place of those already in use, if and when these become broken or fall away from age. These two teeth are simply poisoned daggers, either channeled from the root to the tip, or hollow through-



Courtesy N. Y. Zoological Society, Photo Elwin R. Sanborn

CRYSTALLIZED VENOM AND SNAKE FANGS

(1) Bushmaster, (2) Lancehead, (3) Rattlesnake

The black lines are horsehairs drawn through the fangs to show that they are hollow The hollow fang in working principle is very much like the needle of a hypodermic syringe.

out their course, in order that they may conduct the venom from the sac in which it lies. In some the poison fangs may preserve the natural position of teeth when the mouth is closed, but in the majority of species the fangs fold back upon the gum when the mouth is shut, after the fashion of baleen in the mouth of the whale. When the mouth of the snake is opened to strike at a victim, the teeth are erected by a muscular movement which compresses the poison sac, causing the fatal fluid to pass down the channel either through the tooth or upon its grooved exterior. The fangs are driven into the victim's flesh, and, as they penetrate, the venom is injected as by a hypodermic syringe.

The result, from some species, is death: and from others intense suffering. The poison of the deadliest snake is held to be quite harmless if received by way of the mouth into the digestive system, but, introduced into the blood, it is as fatal as a bullet through the heart. When the poison has done its work, the snake eats its victim, unless the latter be too large. Its venom is mainly employed for destroying the creatures which are to form its meals. But as a snake must live to eat, it turns its frightful weapon against an intruder likely to injure it. This accounts for the number of deaths from snake-bite in India; not necessarily wanton aggression on the part of the snake.

The cobra stands at the head of all the poison snakes in the popular mind, in which it represents the very embodiment of evil. We hear of it chiefly in India, but, of the ten species, only two are found in that great peninsula. There is one in the Philippines, while Africa has the remaining seven species. The cobra haunts human habitations during the rainy season, and makes its way into roofs as easily as into sheds and wood-heaps.

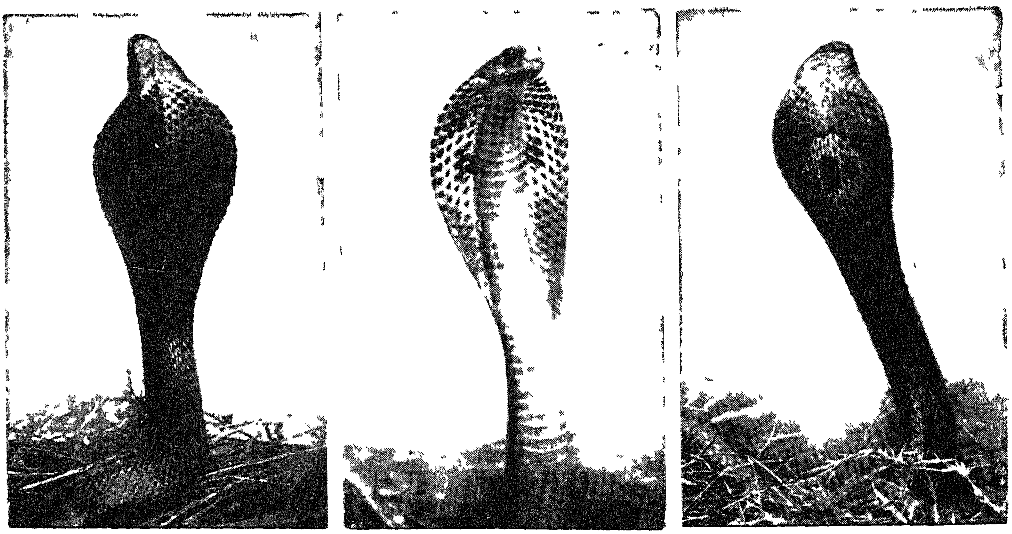
To understand the climbing powers of snakes, we had better glance more particularly at the mechanism of the reptile, for the climbs are achieved by the same means as the swift glide along the ground which carries the creature whithersoever it will.

Snakes have scores of pairs of ribs — some of them as many as three hundred or so — and each pair acts as a limb. The ribs, articulated together by means of a ball-and-socket joint, are attached at their inferior ends not to sternum, or breastbone, for the snake has not a vestige of one, but to a series of large scales upon the abdomen By means of these scales, to each one of which a pair of ribs is joined, the snake is able to grip any inequality in the ground, each pair of ribs pulling forward the scale to which the ribs are attached The whole form one long foot. Some snakes, those especially that live chiefly in trees, have a decided keel which gives a further purchase and enables them to ascend readily any sort of trunk affording them a grip.

Snakes cannot travel upon a perfectly smooth surface. Another thing which a snake cannot do is to move in vertical curves as old pictures represent. Like a twisted arrow it glides, but its undulations are always horizontal. Vestiges of the hind legs of the snake are to be found concealed beneath the skin of some species, but the later method of progress seems quite satisfactory.

It is with the cobra, with his menacing, expanded hood, that the Hindus and Arabs exhibit their powers of "charming". The scene is familiar to the traveler, and its description to the reader. The secret of the "charming" is less well known. What really happens, before the show begins, is that the owner of the reptile, thrusting a piece of cloth near the mouth of the reptile, fastens its fangs in it, then breaks or pulls them out. This done, the poison sac is cut out or burnt to prevent it from being renewed. Fangs may grow again, and in all likelihood will, but once the poison sac is gone there can be no flow of venom into the mouth.

There is a more formidable cobra than the one which we have been considering, and that is the king-cobra, or hamadryad which lives mainly upon other snakes, poisonous or non-poisonous, and feasts with as little ceremony upon another cobra as upon an innocent constrictor. The king-cobra is more to be feared than most poisonous snakes, for this one will attack a man with less provocation than the rest, which will avoid combat when possible, striking only when attacked or believing themselves in danger. The king-cobra does not wait for the danger to come to it, but strives to get its blow in first.

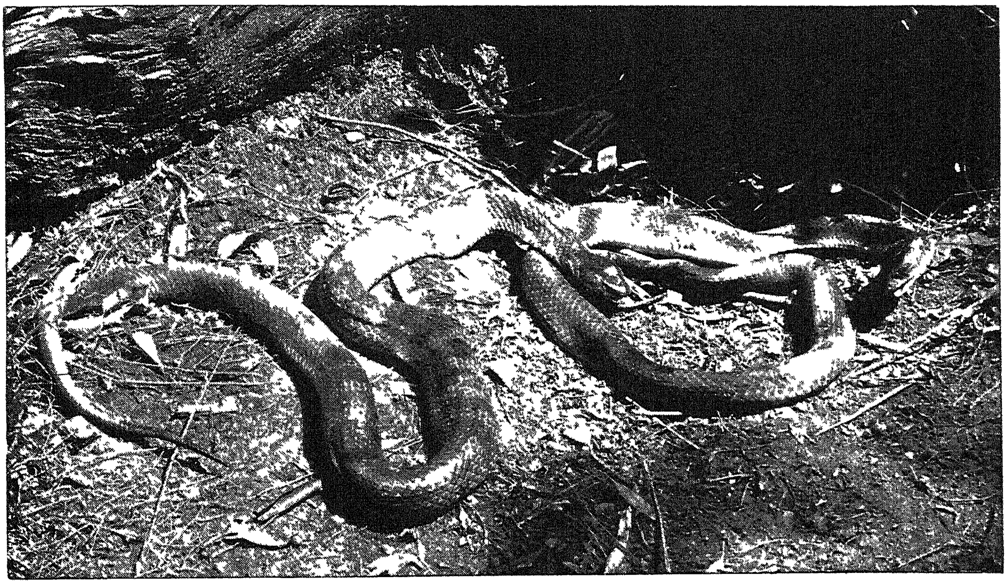


THE BLACK COBRA THE SPECTACLED COBRA THE KING-COBRA

There are one hundred and eleven species of snakes found in North America, of which ninety belong to the family Colubridæ. Two species of blind snakes (Glauconidæ) and four species of boas (Boidæ) are found in the southwest and represent rather large tropical families of snakes

Our species are small and unimportant although the Rosy Boa of Southern California and Arizona is a truly beautiful creature. It is to this family that the giant pythons of Africa and the tremendous anacondas of South America belong.

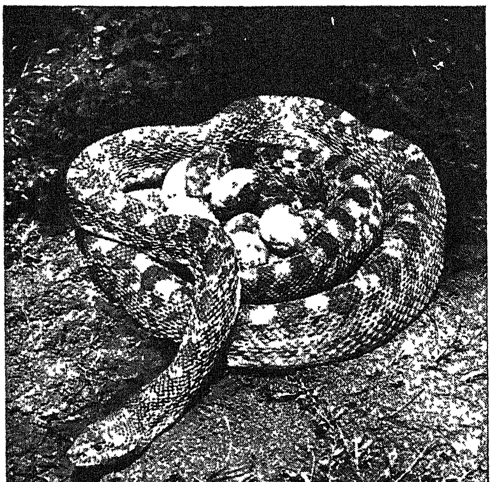
The colubrine snakes, including practically all of our common snakes, are entirely harmless and of considerable economic importance in that they destroy small rodents They are grouped into thirty-three genera, among the best known of which are the garter snakes, most abundant of all North American serpents, the small brown snakes, the racers or black snakes, the rat snakes, the bull-snakes, the green snakes, the ring-necked snakes, the king-snakes and the hog-nosed snakes or spreading adders. The family likewise includes, however, the dangerous coral snakes of our Southern States, the more dangerous because they are so beautiful and apparently so inoffensive. Here also belong the deadly cobras, and the kraits of India, and the Australian death-adder. The coral snakes are ringed with bright scarlet, yellow and black, a color pattern that is simulated by several of the harmless king snakes. The banded krait, which is known to attain a length of six feet, is popularly considered the most terrible, but experiment has shown that the common krait is actually the more deadly. The latter is a superb climber, and leaps with death in its fangs from all parts of an Indian dwelling Possibly none of the kraits is as potent as the death-adder of Australia; but, though this latter is held in mortal detestation by natives and Europeans alike, relatively few deaths are caused by it, owing to the sparse population in the areas where this reptile roams



MALE AND FEMALE OF SHORT DEATH-ADDER OUTSIDE THEIR LAIR

As has been noted, the sea-snakes, to which we next come, are really the most poisonous of all. They are not to be relegated to a separate family, for investigations go to prove that they began where the rest of the colubrines began, and have increased in virulence with the needs of the life which they pass in the sea. There are four genera of them, and so thoroughly have they adapted themselves to life in the sea and tidal waters that only one, the broad-tailed sea-snake, ever quits the water except by accident Needless to say, the sea-snakes breathe atmospheric air by means of lungs in no respect different from those of terrestrial snakes. Their existence is, of course, no support of the foolish tales brought forth every summer by inexperienced visitors to the seaside as to the "sea-serpent". The difference be-

tween a sea-snake and a sea-serpent is this: that the sea-snake is excessively abundant in actual life in the warm waters of the Indian Ocean, in the tropical western Pacific reaching from the Persian Gulf to New Guinea, northern Australia, and from the western coast of Africa to the western shores of tropical America, and away to New Zealand, Manchuria and Japan; while the sea-serpent is a myth swimming within the ken only of the imaginative, who are incapable of recognizing darting sea-birds in a line, or a school of porpoises in column, or the fins of sharks or whales, or even an unwontedly elongated variety of ribbon-fish. That is not the only distinction, but perhaps it will suffice.



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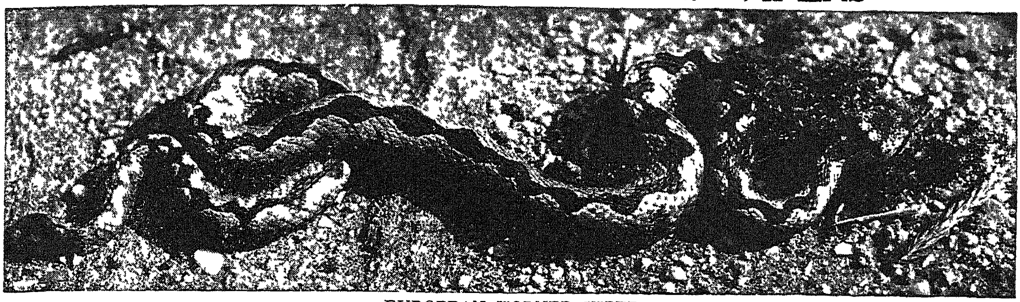
BULL SNAKE AND ITS EGGS

Coming to the viperine family, we reach one of the deadliest assemblages of snakes. All are poisonous, even the least noxious, the common or British viper. There are a dozen genera of vipers; and the mere names of some of them, such as Russell's viper, the puff adders, the various horned vipers, the rat-tailed viper and the rattle-snakes, suffice to inspire a sense of discomfort in anyone familiar with the habits of the reptiles themselves. The largest European representative of the group is the long-nosed or sand-viper. Russell's is one of the plagues of India, deadly to cattle, and responsible, no doubt, for many of the 90,000 included in the annual "kill" by wild animals. The puff adder is the most terrifying in appearance of all the poisonous snakes. It inhabits sandy wastes, and upon being disturbed raises its hideous, triangular-shaped head, and draws in a deep breath, which it respires with a hissing, puffing sound; and woe betide the living thing within reach, be it horse, camel or man.

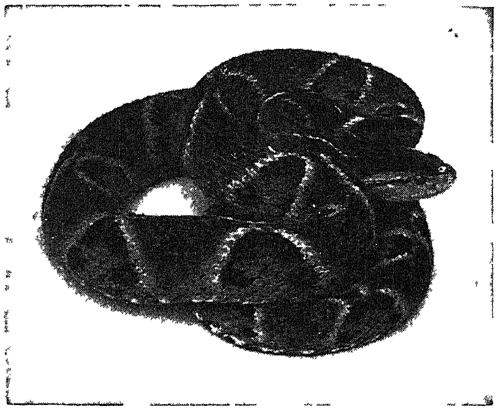
Perhaps the horned viper is even more dreaded than the puff adder, for this malignant foe of all forms of life coils itself up on caravan routes, in the depressions caused by the feet of pack animals, leaving only its head exposed, to dart with a unique sidelong action, and inflict its fatal bite, from which a healthy man will die in half an hour. It is believed that Cleopatra's asp was a horned viper, possibly *Cerastes vipera*.

As the king-cobra, measuring nearly fifteen feet in length, is the largest of all poisonous snakes, the rattlesnake is, with the exception of the bushmaster, the largest of all the vipers. The length of the female diamond rattlesnake is sometimes over eight feet. Pit-vipers — so called from a deep depression upon the upper part of the head, of unknown purpose — range throughout Asia and America, but the rattlesnake is peculiar to the New World. This viper is notable for the singular rings of hollow, quill-like horn at the end of the tail, interlocked one with another, yet so elastic as to permit considerable vibration, resulting in the "rattle" from which the reptile derives its title. Naturalists do not agree as to the purpose of this rattle The old idea that it is a merciful provision of nature to warn the victim of its impending doom is, of course, nonsensical; that is not nature's way. That it is intended to frighten off hostile birds or animals seems more possible, but as the bark of a dog would but call a puma to feast upon the dog, so the rattle of the snake would summon pig or other predatory animal or bird to banquet on snake. There may be something in the suggestion that the rattle, whatever may have been its origin, serves as a means of communication, for whenever one rattlesnake shakes his "quills", every other rattler within hearing will respond in like fashion.

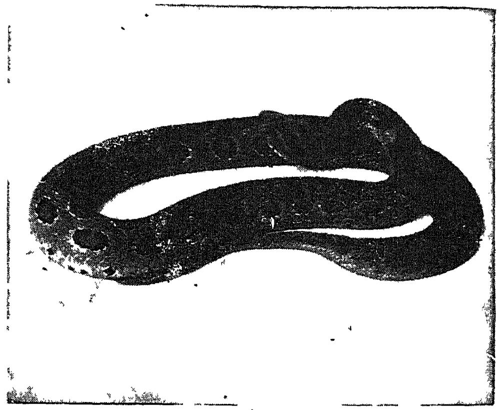
SOME OF THE VENOMOUS VIPERS



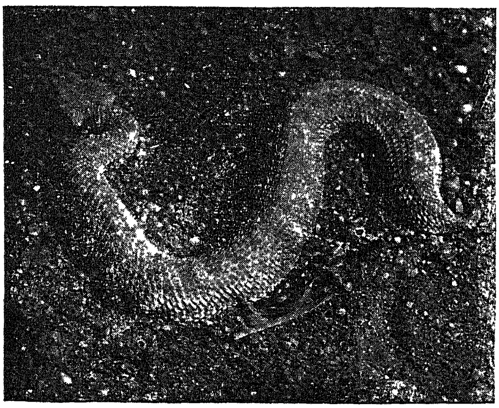
EUROPEAN HORNED VIPER



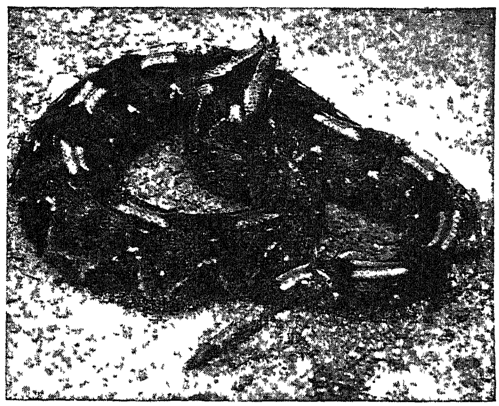
LANCEHEAD VIPER



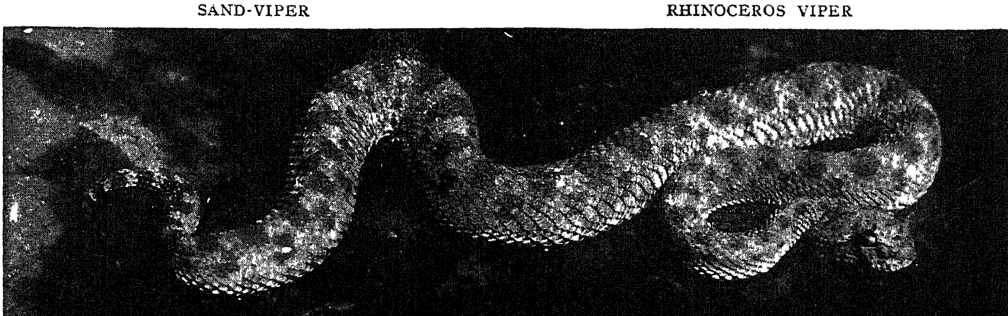
RUSSELL'S VIPER



SAND-VIPER

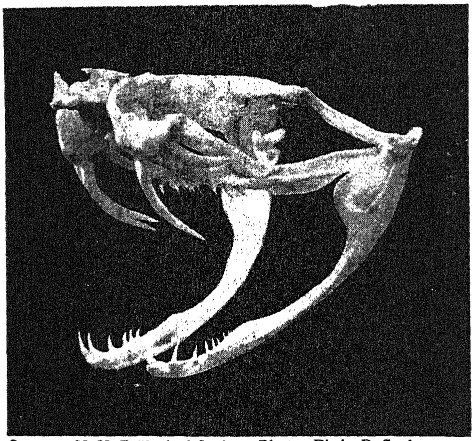


RHINOCEROS VIPER

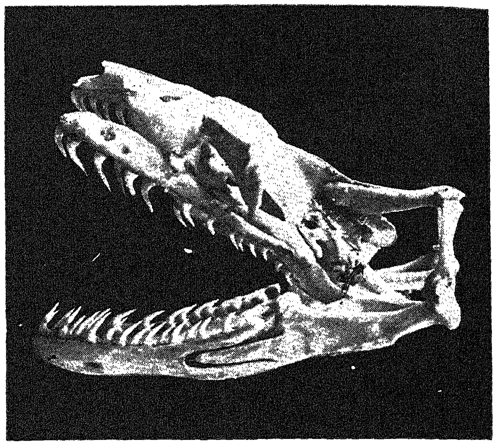


Courtesy N. Y. Zoölogical Society, Photos Elwin R. Sanborn

AFRICAN HORNED VIPER



Courtesy N. Y. Zoölogical Society. Photos Elwin R. Sanborn
SKULL OF BUSHMASTER



SKULL OF BOA

Reptiles, as a rule, display but slight regard for their kind, unless possibilities of snake eating snake be toward, but the rattlesnake is famous for its winter parties. It is clearly established that in the colder latitudes these reptiles, where they still survive in large numbers, make quite considerable journeys in order to spend the winter in company, twisted and entwined "like a huge mat wound and interlocked together, with all their heads, like scores of hydras, standing up from the mass". So the picture is described by one who in his youth saw between 500 and 600 of these reptiles killed at a single cave.

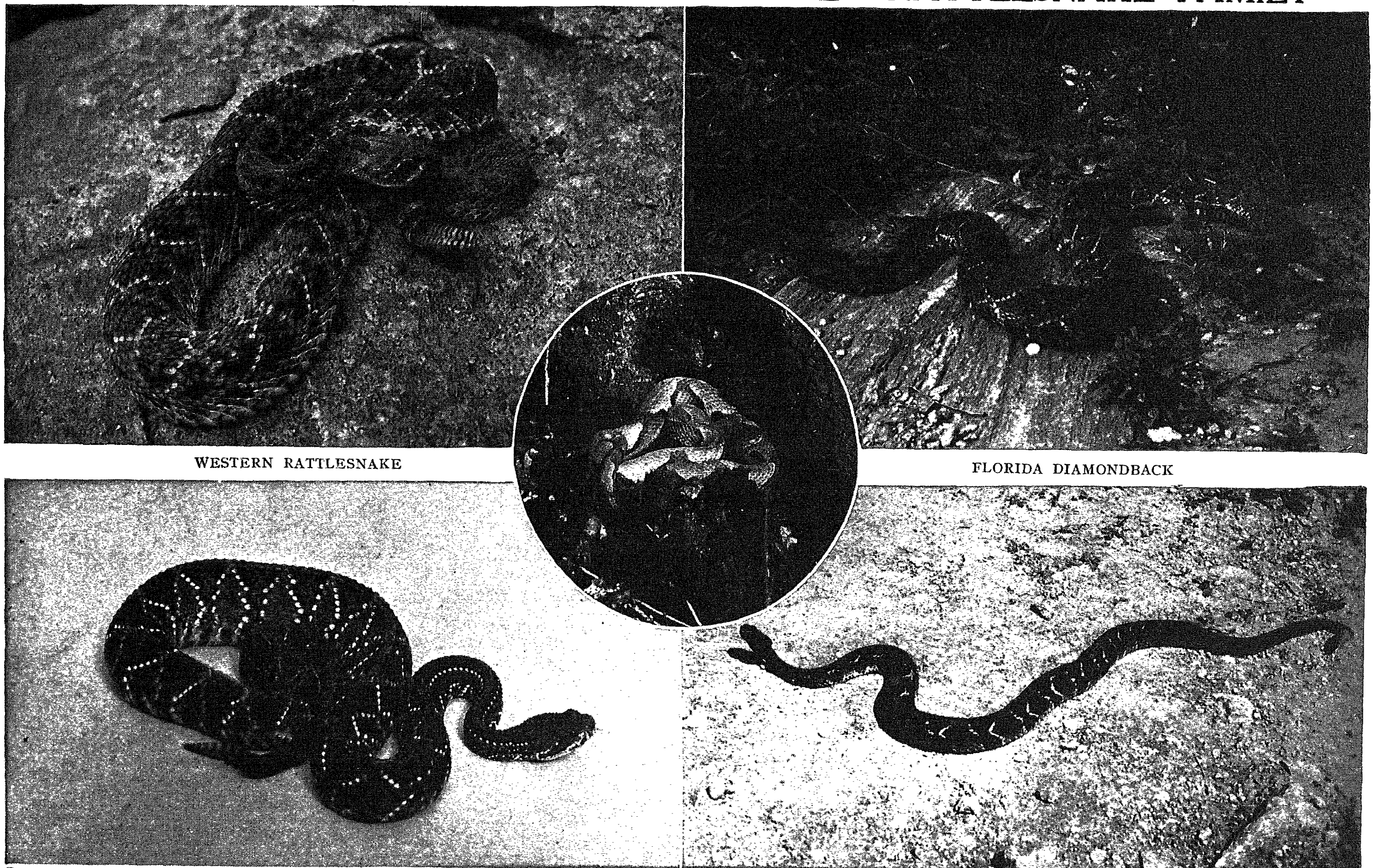
© E. M. Newman
DR. VITAL BRAZIL EXAMINING A DEADLY SNAKE
At the Butantan Serotherapeutic Institute of which he is director.

With the advance of man into the wilds rattlesnakes are slowly vanishing. Man and his pig are accounting for these, the deadliest reptiles on the American continent. Man has his gun and his hatchet; the pig has his appetite and immunity to snake bite.

There are thirteen species of rattlesnakes and two pit vipers, without the rattles, found in North America. Two of the rattlesnakes, called "ground rattlers" or "pigmy rattlesnakes" are relatively small and inoffensive, but the other eleven vary in length from 3 to 8 feet. Most of them are found in dry, sandy or rocky situations, but the water moccasin, one of the pit vipers, frequents the cypress swamps of the south. The other pit viper, called the copperhead, lives in dry woodlands as far north as southern New York State. The best known of the rattlesnakes are the banded or timber rattlesnake of eastern and central United States, and the diamond-backed rattlesnake of the southeast. The bushmaster and the "fer-de-lance" of Central and South America are among the most dangerous of all serpents. They belong to the pit vipers, having no rattles.

Remedies for snake bites: Remedies for snake bites are almost as numerous as snake stories, and owe their sale to the fear inspired by all reptiles and supposed cures effected upon individuals bitten by non-poisonous snakes. Whisky and various other stimulants are all right in small

SOME OF THE MEMBERS OF THE DEADLY RATTLESNAKE FAMILY



WESTERN RATTLESNAKE

FLORIDA DIAMONDBACK

Courtesy N. Y. Zoölogical Society, Photos Elwin R. Sanborn

SOUTH AMERICAN RATTLESNAKE

COPPERHEAD

NORTHERN BANDED RATTLESNAKE

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A SOUTH AMERICAN SNAKE FARM

This is a photograph of the larger of the snake parks at the Serotherapeutic Institute of Butantan, near the city of São Paulo, one of the objects of which is the furnishing, free to the poor, of antivenom serums It takes about a month in winter and a fortnight in summer for a snake's gland to replace the venom extracted The former long death roll, especially among the barefooted laborers on the coffee and sugar *fazendas*, from snake bites in this peculiarly infested country, has shrunk to almost nothing as a result

doses to stimulate heart action provided they are used with some antiseptic dressing for the wound, but large doses render the subject much more liable to the poison

The best procedure is to bind a tight ligature above the wound, then to lacerate the flesh about the wound to cause profuse bleeding, and apply a one per cent solution of permanganate of potash Sucking the wound to drain out the poison is advisable if the mouth is free from any scratches.

The making of "anti-venom" serums has become a well-established business in certain countries, particularly in Brazil, where snake farms are maintained for the purpose of securing the venom The serum is usually secured from horses which have been immunized by repeated small injections of the poison. A different serum is made for each type of venomous snake, and one of a more general nature for use when the kind of snake is not known.

Returning to the pythons and boas, we reach a group of snakes whose dimensions render credible the evidence of the rocks as to the size of the serpents of old time The average work on natural history hardly gives us a true notion of the size of these reptiles. The naturalist seeks to preserve an impartial balance between his own skeptical attitude towards measurements of animals with the largest types of which he is never brought face to face, and the figures enthusiastically inscribed upon the diary of the traveler. Hence we have the medium, average size of the monster snakes represented on the one hand as the maximum, and on the other hand the hunter's exceptional trophy represented as though it were the average.

The pythons and boas together form one family of some twenty genera, the whole being grouped as the Boidæ. Of the pythons we have some half-score species,

A MONSTER SNAKE OF THE TROPICS

Courtesy N Y Zoological Society, Photo Elwin R. Sanborn

REGAL PYTHON

distributed over tropical and South Africa, southeastern Asia and Australasia. These are the largest of all snakes with the exception of the anaconda. So long as a snake at large is healthy and active enough to continue to feed and frequently to cast its skin, there seems no reason why it should not, in favorable circumstances, continue to grow, as a crocodile grows. Even the Malayan python, long regarded as among the smaller of the brigade, is now found to exceed thirty feet in length. The average is fixed at from half to two-thirds of that length. Expert swimmers, the pythons are largely arboreal, but the bulk of their prey is caught upon the ground, where small deer, half-grown sheep, and larger animals are seized, crushed and consumed. The method of taking their prey is the same in all the species. The animal is firmly gripped with the back-curving teeth, which make it impossible for the victim to escape. Then the mighty coils are flung round about the body, which is crushed by a crescendo of pressure, until it assumes a sausage-shaped mass.

As the viper rears its head and seeks to bite the moment it is liberated from the egg, so the young python almost from birth shows the ability to crush and smother. At any rate, pythons, incubated in private, when ten days old flung themselves round the bodies of sparrows and crushed them in a way that would have had the approval of the mightiest adult specimen. The free snake is infinitely more lively and powerful than the captive, being in constant training, so to speak, and not fasting for such prodigious periods. The manner in which large kills are swallowed is this. The lower jaw, as we have seen, is elastic, the bones being separate, and held together by a powerful, pliable ligament. Where the brute grips, there it holds, but, in order to swallow, it has practically to draw itself on to the body, as a glove upon the hand. This is effected by the lower halves of the jaw practically walking forward alternately, a fresh inward-pulling grip being secured at each step, while mucus is freely discharged upon that portion of the body within the mouth, so lubricating it in its progress down the throat.

Whether a large python or boa will eat a man or not is disputed. There is presumptive evidence against the reptile, from the fact that if it once bites it must swallow, or die in the attempt. One has been known to eat a blanket, which it accidentally caught in its teeth, and a python at the London Zoo, measuring nine feet, swallowed another only a foot less in size. A similar thing happened when a python of eleven feet, snapping at a pigeon which was in the jaws of another python of more than nine feet, caught the head of the latter and was compelled to swallow the snake at the end of the pigeon. This it did during the night, and the keeper in the morning found two snakes in one, the outer specimen bulging at every scale. The first case was, however, the more remarkable, for the victim there had doubled up in the gullet of his destroyer, and had extended him to treble his normal girth for about a yard beyond the head.

The anaconda, monarch of the boas, is commonly credited with a length of from 30 to 40 feet, and girth proportionate; and although certain naturalists sniff at stories of forty feet of anaconda, yet there is no challenging the careful statement laid by Major P. H. Fawcett before the Royal Geographical Society in 1910. In an unadorned narrative he told of killing one 65 feet in length, while another party reported to him one of 85 feet. The second may stand as a statement "not proven", but Major Fawcett's measurements must inevitably find a place in our natural histories if their editors keep abreast of unchallenged data.

The anaconda is python-like in habits, living a great part of its time in the water, and climbing trees with the ease and certainty of some mighty vine endowed with animal life and powers of free locomotion. Snake life reaches its zenith in the anaconda; and South America, of which it is a native, is exactly the place in which we should expect to find it, that land of strange, uncanny giants, of which this reptile is at present the only known surviving relic. If giant sloths and contemporary Titans are extinct, the anaconda remains, an equal marvel.

THE PLANTS OF THE SEA

Their Coloring and Susceptibility to Depth, to Temperature and to Saltness

VEGETABLE LIFE IN NEPTUNE'S GARDEN

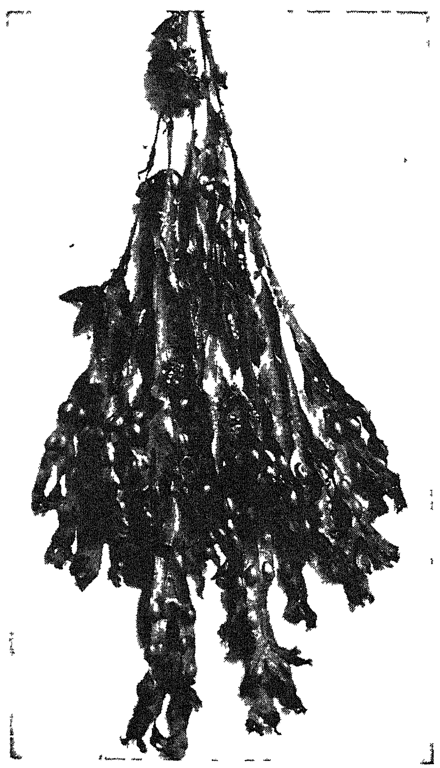
THE study of life is always interesting, no matter what phase of it be chosen, but there is no more fascinating field than that of marine biology. There is always something mysterious about the living things in the sea — a feeling that no matter how much we may find out, there is more, much more, that remains undiscovered. Lands and continents may be explored and surveyed until not a square yard remains unknown, but no man can probe to the uttermost the depths of the ocean, nor examine more than a fraction of its contents. We know much of the monsters of the animal world that in olden times ranged its waters, and the largest forms of animal life still disport themselves there; but scientific knowledge of the plants of the sea is infinitely less advanced, and indeed has only in recent years made much progress.

Considering how universally distributed are the sea plants, or sea*weeds*, as we curiously term them, it is rather remarkable that ancient literature should have such sparse references to them; but, as a matter of fact, one finds only the most superficial mention of them. The Bible refers to them but once, in the words of Jonah, "The depths closed me round about, the weeds were wrapped about my head." Latin and Greek authors passed them over with similar contempt or ignorance. The earliest writers on biology frequently described many sea animals as plants, which is not surprising when we consider how unlike animals many of them undoubtedly are at first sight.

The prevailing color of land plants is the universal green, only relieved by the brilliance of the varied parts of the flower and the color of the bark of trees, but there is no such uniformity in the coloring of seaweeds. Indeed, it is their wonderful coloring that would first attract the attention of the observer looking at a forest of seaweed in clear water. Nothing more beautiful in coloring can be imagined. No wonder that the colors were taken as a basis of classification, a basis which still remains in the names given to the different groups. Thus we have the *Rhodophyceæ*, or red seaweeds; the *Phæophyceæ*, or olive-brown seaweeds; the *Chlorophyceæ*, or green seaweeds; and the *Cyanophyceæ*, or blue-green seaweeds. Nor is this such an unscientific method of classification as might be imagined, for it very nearly agrees with a classification that would be made were structure and mode of growth taken as the basis in the place of color.

When we look into this matter of coloring in sea plants, we find that it does not differ so fundamentally from that which obtains in land plants as would appear. In their ultimate color-composition the sea plants are all really green, just as are ordinary plants, and by virtue of the same pigment, chlorophyll. Where they differ is in having some other pigments in addition, the presence of which more or less obscures the green chlorophyll. Of these pigments there are four, termed respectively phycoerythrin, or the red pigment; phycophæin, or the brown pigment; phycoxanthin, or the yellowish-brown pigment; and phycocyanin, or the blue pigment. The discovery of these varied coloring matters explains at once the wonderful combinations and shades found in sea plants.

They all differ from chlorophyll in one important and interesting feature — namely, that they can be dissolved out of the sea plants by simply soaking them in fresh water, when the colored plants present the ordinary green of their shore relations. Chlorophyll is insoluble in water, and hence remains in plants so treated. Some fresh-water plants exist which are also colored similarly, but, nevertheless, these pigments are the special features of the sea plants, and their presence is due



BLADDERWRACK

to the environment in which the plants pass their existence.

The colors of sea plants indicate in a somewhat rough-and-ready manner the depths at which the plants grow, though there are numerous exceptions. Thus the seaweeds found near the level of the high-tide mark on the shore approximate in coloring to the land plants — that is, their prevailing color is green. Farther down the beach or rocks, covered at high tide and laid bare at low tide, we find the plants of the prevailing olive-brown tint.

Underneath these and sheltered by them red forms are found; and these, too, may be discerned in rock-pools at the bottom. At the lowest tide-level and extending into the shallow sea we notice multitudes of brown seaweeds with red ones intermingled with them, but it is only in the greatest depths which support plant life at all that the red members are found by themselves.

There is a limit to the depth at which sea plants are enabled to thrive. They become fewer and fewer after twenty fathoms (120 feet), and it is very unusual to find them beyond a depth of fifty fathoms (300 feet).

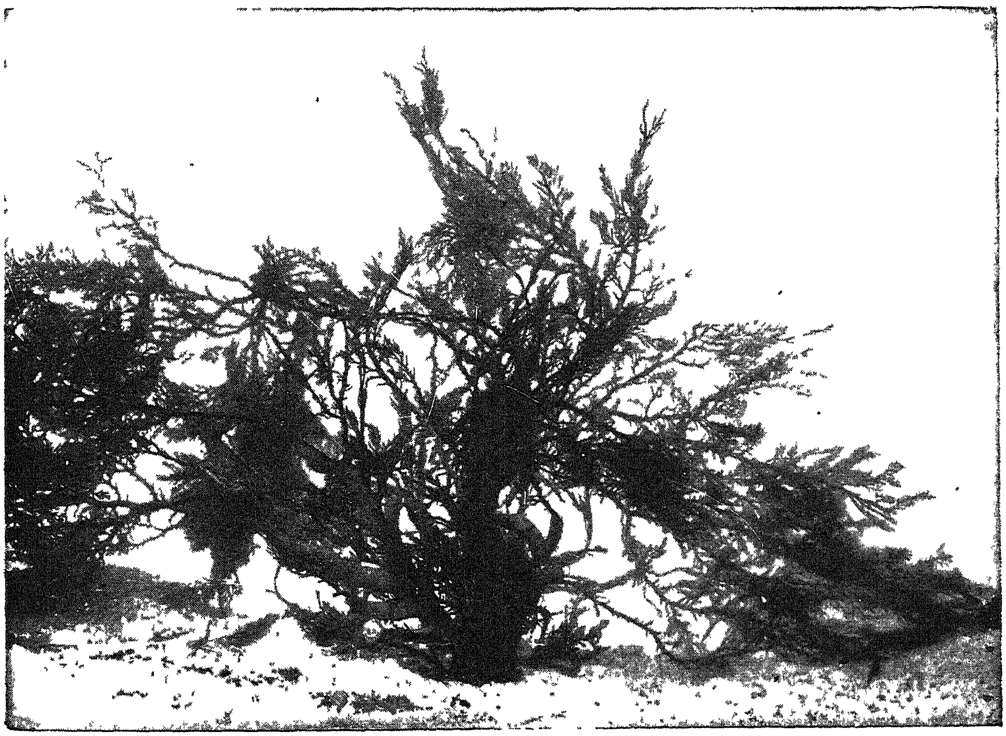
What determines the depth at which sea plants can grow? Doubtless it is a question of the penetration of sunlight through the water, light being necessary for chlorophyll to perform its all-important functions in connection with processes of nutrition. But the sea is not in utter darkness in the daytime until we reach a depth of some seven hundred fathoms or less, and it might therefore be supposed that plants would flourish up, or rather down, to that depth. As a matter of fact, however, they do not.

There is another intervening factor besides that of the mere penetration of light. There is a qualitative change as well as a quantitative change in the light which passes down through the water, and this is the further explanation. Light is composed of various rays, as we know, and the different rays have different functions and properties. Some are more active than others in the work of assisting chlorophyll in its function, and, curiously enough, it is precisely these which are first intercepted by the sea-water. The only rays of light which reach the greater depths are the blue rays and the green rays. This would suggest that the additional pigments found in sea plants, which we have named above, have been evolved as additions to chlorophyll to make up for the qualitative change in light which takes place in these depths

Possibly they assist the chlorophyll to make use of what light reaches the plant, rendering it more easily affected by light. Or perhaps they afford some kind of protective influence against the excess of the

blue rays which penetrate. The second view is regarded as the more probable by Mr. George Murray in his excellent book on the "Study of Seaweeds", to which we owe many of the facts here stated. Similar protective functions are ascribed to pigments in certain land plants, which supports this view.

It is true that minute and other plants have been obtained from great depths occasionally, but they do not live there under normal conditions. Probably they have been carried down by currents. So that we have the outstanding point that color, which is of no value in classifying land plants, is correlated with other characters in sea plants; and we need not be surprised at that, when we remember that in the sea color is of immense importance in connection with the performance of the nutritive functions. Light, then, chiefly determines the depths at which sea plants live.



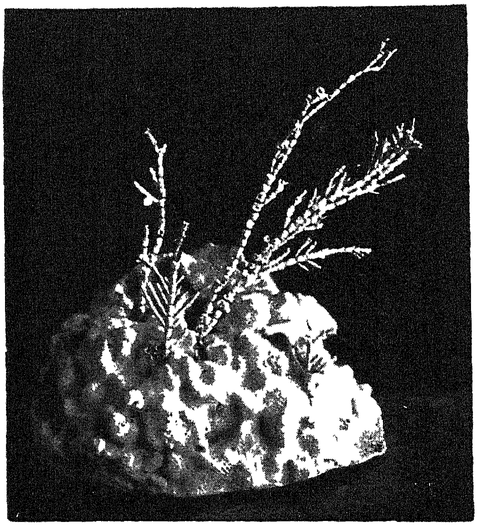
SCARLET PLOCANIUM, ONE OF THE MOST ABUNDANT OF THE RED DIVISION OF SEAWEEDS

The second great factor in the life of sea plants is the temperature of the water, and it is this factor which is responsible for the geographical distribution of sea plants. Sea temperature does not vary in anything like such great degree as does that of the air on land, neither diurnally nor seasonally. It is much more constant than we are apt to suppose, the changes we appear to feel in it, when bathing, for example, being much more due to the changes in the air we are in than to changes in the temperature of the water. Thus we often imagine the sea-water is very warm at night, tested, it may be, by dipping the hand over the side of the boat. It is the night air which has become colder, and gives us that impression. Living, therefore, in a fairly constant temperature, sea plants naturally are very susceptible to changes in that temperature. They are not accustomed to them. Hence the necessity of careful regulation of the temperature in aquaria if the plants are to flourish.

Other factors, too, play a part in the life in the sea Notable amongst these are the degree of the saltness of the water, the kind of bottom on which the plants are growing, and the amount of tidal variation in any

given spot. So sensitive are seaweeds to temperature changes that it is difficult to transfer those from great depths to artificial surroundings, especially in summer. They should be packed in ice, and must have a cool place to grow in, where direct sunlight cannot penetrate. They resent quick changes of water and exposure to air.

In order to really study their growth with accuracy they must be suspended in the sea at their natural respective depths, and anchored in some convenient manner. The salinity of the water has not so great an adverse effect as has variation in salinity, as may be observed in estuaries and



BRITISH CORALLINE ON THE SHELL OF A LIVING LIMPET

places where fresh water is constantly arriving in varied amount according to the rainfall.

Mr. George Murray quotes a very interesting case bearing upon this point. "A canal connects the sea with a lake that receives almost all the fresh water of Mecklenburg, and many species of seaweeds grow in this lake at places where the salinity is almost nil; while almost all are absent from the canal, which conveys sometimes salt water and sometimes fresh." Thus we see that it is the alterations in salinity rather than the degree of salinity which adversely affect the growth of the sea flora.

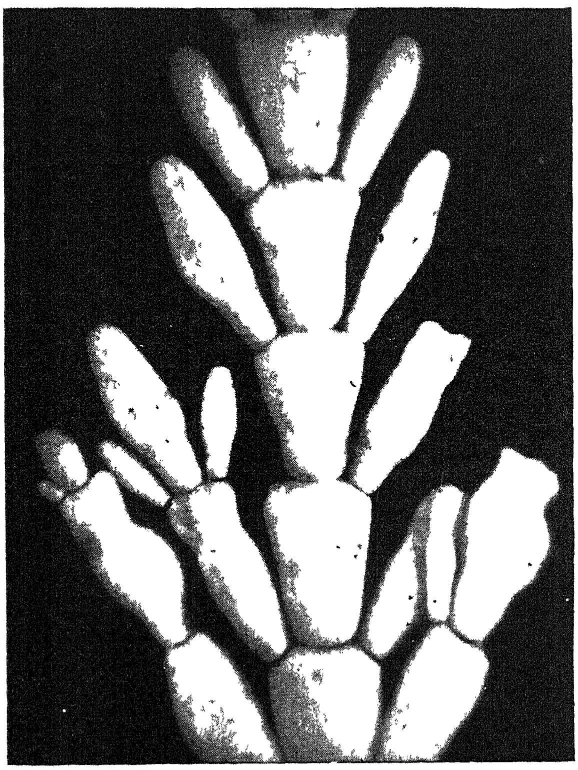
Among the primary factors in the distribution of sea plants in space must be reckoned the great and small ocean currents, which act also as agents of seed dispersal for land plants, as we have previously noted. But in the land plants, it will be remembered, we found many curious and varied adaptations to enable them to take advantage of ocean and other water currents as agents of dispersal. In the case of the sea plants there is no need for these special adaptive arrangements. The ocean currents seem to control what may be termed the climate of the sea-water, much as high ranges of mountains affect land plants. We often find the flora on two sides of a mountain range differing widely, and in similar manner the sea flora on the two sides of a continent exhibits wide variations from the effect of currents. Thus the West Coast of Africa is washed by a cold current coming up from the south, whereas the East Coast is under the influence of a warm Mozambique current from the north, and the species of sea plants vary accordingly. The flora of the different portions of the Gulf Stream is similarly varied, exhibiting the plants of the temperate region in the Shetland Islands and the Arctic flora of Cape Farewell, both these being on the same parallel, but the latter influenced by the cold current from the east of Greenland.

The analogy between plant distribution on land and in sea may be further illustrated by observing how the vastly increased means of communication in the modern world plays a part. This is, of course, very clear in the case of land plants, but it acts, too, for those of the sea. Iron ships carry great numbers of seaweeds from place to place, more so than did the old wooden vessels, whose copper bottoms protected them. True, the great mass of sea-water is continuous, and there is nothing of a physical nature to offer insurmountable barriers to dispersal, but the varying temperatures of seas which communicate with each other determine the exact species that will flourish in each. Lastly, in this connection, it may be noted that the species which the various oceans

have in common are, as perhaps might be expected, those of the smaller type rather than the great sea plants.

A very interesting fact is observed if the flora of the two polar regions be compared with each other. There are no less than fifty-four species at least — perhaps more — which are common to the Arctic and Antarctic waters, but which do not occur in the intervening tropics, and these plants must have been divided from each other by this intervening mass of warmer water from time immemorial — indeed, ever since the world has known the meaning of climatic differences. Let us inquire how this striking resemblance comes about.

Sir John Murray, in the reports of the *Challenger* expedition, puts forward the following theory on the point. "In Carboniferous times the surface temperature of the sea could not well have been less than about 70° F., and the same temperature and the same marine fauna prevailed from equator to poles, the temperature not being higher at the equator. In early Mesozoic times cooling at the poles and differentiation into zones of climate appear to have commenced, and temperature conditions did not afterwards admit of coral reefs in the polar area, but the colder, and hence denser, water that in consequence descended to the great depths of the ocean carried with it a large supply of oxygen, and life in the deep sea became possible for the first time. There have been many speculations as to how a nearly uniform temperature could have been brought about in sea-water over the whole surface of the earth in early geological ages, as well as to how sufficient light could have been present at the poles to permit of the luxuriant vegetation that once flourished in those regions. The explanation that appears the most satisfactory is the one which attributes these conditions to the very much greater size of the sun in the early stages of the earth's history — an idea first introduced into geological speculations by Blandet, who likewise discussed the relations of Arctic and Antarctic faunas — together with the greater amount of aqueous vapor in the atmosphere and the greater mass of the atmosphere."

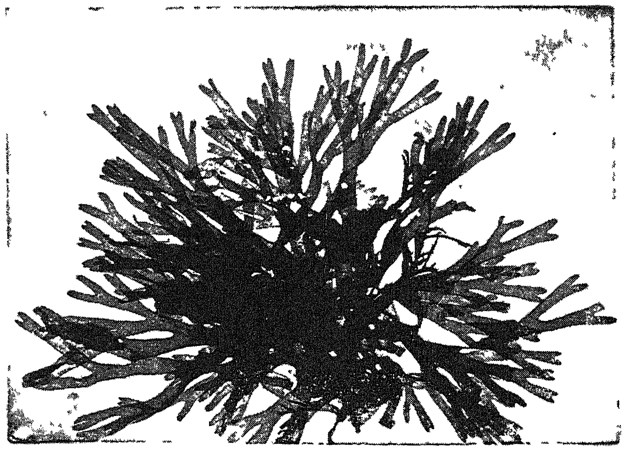


PART OF A FROND OF BRITISH CORALLINE SHOWING STONY STRUCTURE

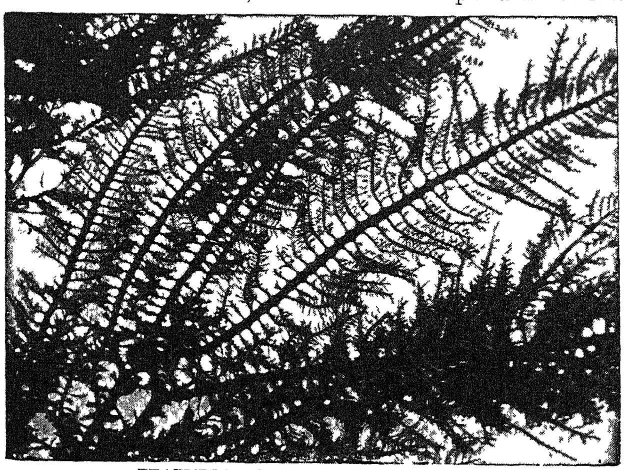
A comparison between the lives of land and sea plants is very instructive, and we may pursue it a little further. It will help us to fix in our minds some of the great general biological principles it has been the object of these chapters to convey. We learned in our early study how dependent is the animal world upon the vegetable for food supply, inasmuch as it is the plant alone which can convert the inorganic matter into the organic. Hence the enormous bulk of land plants. Now apply this to the conditions of sea plant and animal life, and a very interesting point emerges. The vegetables of the sea, so to speak, are only obvious along the coasts, and even here, as we have seen, the plants do not grow to any great depths. This somewhat scanty supply could not

by any chance be adequate to maintain the enormous animal population of the sea, creatures which, for one thing, live far out at sea on the surface of the water, and, for another thing, also descend considerable distances out of the realm of sunlight. How is this disparity made up?

The answer is that it comes from the plankton or floating population of the sea, a population consisting of an enormous bulk of extremely minute plants and animals, so minute that only the microscope reveals their nature, and only visible to the unaided eye when massed together in uncountable millions. Some of the more interesting and better-known members of this population must be mentioned, for they are among the most fascinating of the sea plants. First we have the *Diatomaceæ*, an immense group which numbers in it no less than some ten thousand different species inhabiting all the known waters of the earth. Diatoms are common on stones and the bottoms of fresh-water ponds and streams as well as in the sea. They have been studied in greater detail than most, partly on account of their wide distribution, and also, no doubt, on account of their fascination and beauty.


FORKED DICTYOTA

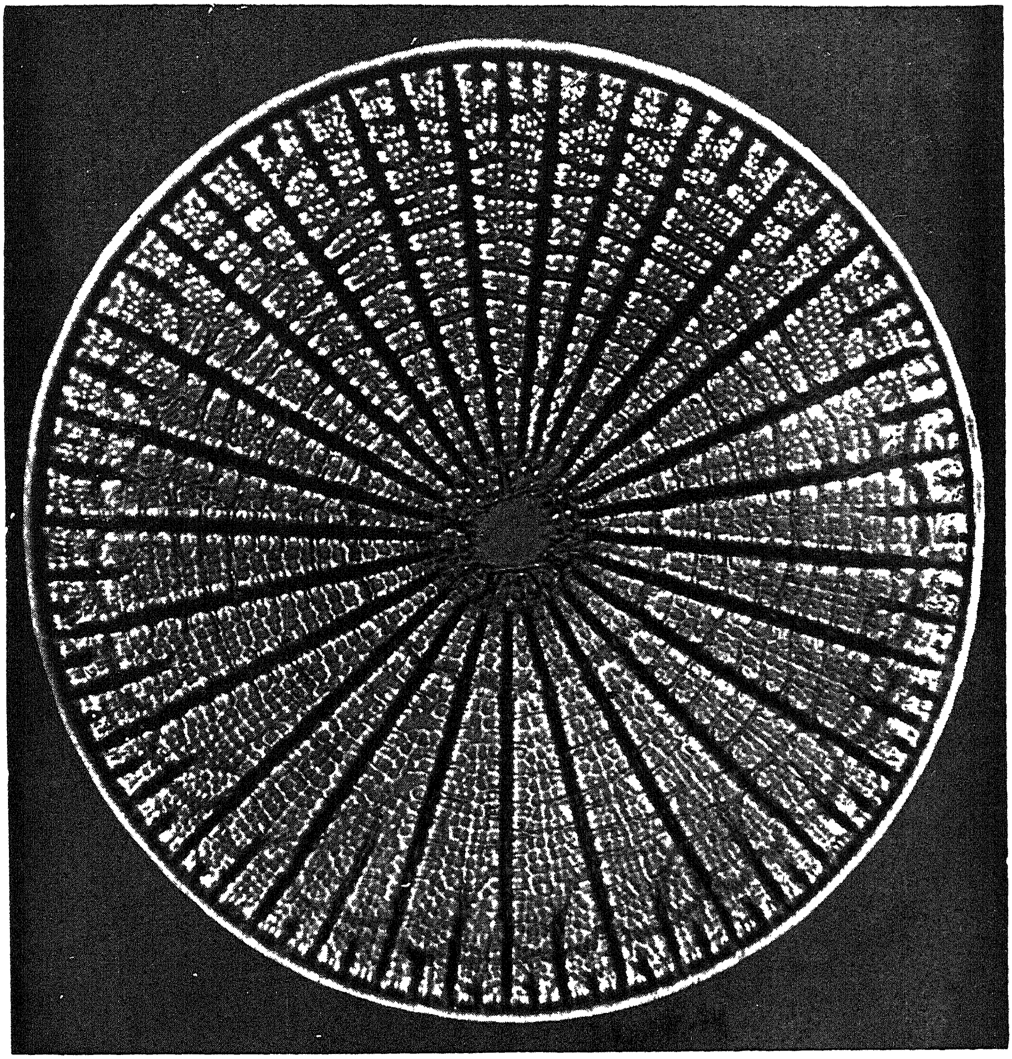
The diatoms are microscopic plants consisting of a single cell in each individual, the envelope of the cell being impregnated with silicious matter. Each individual has two shells termed *valves*, which overlap each other. The arrangement is like that of a box with an overlapping lid. The plants are colored with chlorophyll and an additional brownish pigment, and many species are capable of movement. They reproduce themselves in a peculiar manner, by dividing into a successive number of partitions, each new generation being therefore smaller than the one preceding Then they undergo a kind of spore formation, and the original size of the individual is regained. Like many microscopic forms of life, they sometimes adhere to each other in chains or masses, in the latter case being embedded in a viscous substance. Others live as independent unicellular plants. In the mass they look brown. The great beauty they present is especially due to the marvelous variety of the sculpturing which is seen on the shells, or valves.


FEATHERY PTILOTA — A RED ALGA

Their movements, which are rapid, are always in the direction of backwards and forwards along the plane of their own long axis. It does not suggest the motion of an absolutely free organism swimming in the watery medium. It takes place along the surface of whatever the diatom is resting upon, and is possibly due to the

protrusion of cilia. "That these movements take place with considerable relative force is shown," says Mr. George Murray, "by the observation of Donkin, who saw one species push away another at least six times its size, while other observers state that they have seen this greatly exceeded. The speed of the movement when compared with the rapid dartings of ciliated organisms is slow. The Rev. William Smith estimated the rate at about four hundred times a diatom's length in the space of three minutes."

Although diatoms occur in untold numbers in the sea, and in all seas, they are most numerous in the chilly seas of the northern and southern oceans. When adherent in masses they form a "scum" on the water that has been examined when brought in by surface tow-nets. The individuals composing this mass of scum gradually die, and the silicious shells sink to the bottom of the sea, where they form the famous diatomaceous ooze. Ordinary fish, shell-fish, and the lobster and shrimp group, utilize diatoms as food, and there is no doubt that they constitute the most abundant vegetable food in sea-water. They are preserved as fossils from tertian and quarternary times, and find a use in



A DIATOM, OR WATER-PLANT, MAGNIFIED FROM THE SIZE OF A PIN-POINT

modern life in the well-known tripoli powder which consists of their shells. They are utilized in making dynamite, and in polishing mixtures.

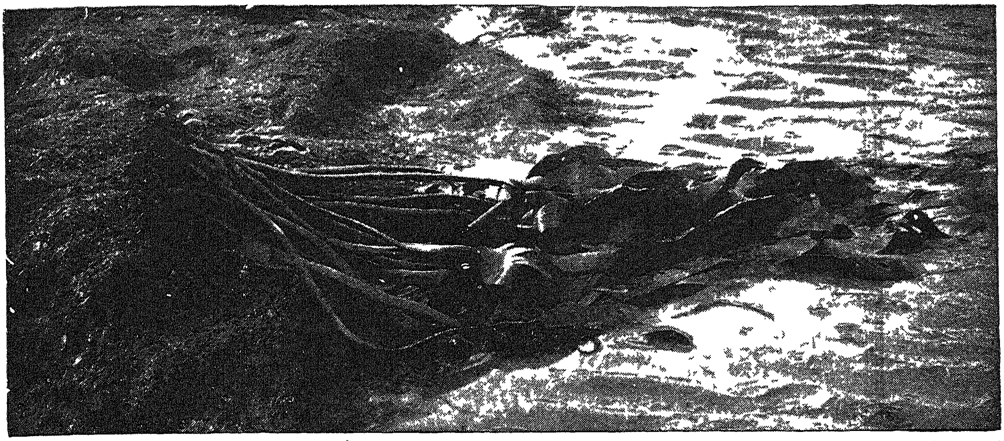
Leaving these fascinating microscopic forms of plant life, we may look for a moment at some more familiar seaweeds, such as may be found upon our own shores almost anywhere. The seaweeds that can be most easily seen are naturally those which grow about the level of the tide when high, and amongst the most common of these are large, flat forms known as the *Ulvaceæ*, a group of the green algæ. The mass of the plant, or the thallus, is irregular in outline, sometimes branched, and may be hollow, the space being between one or more layers of cells which have separated in growth. They are found all over the world, and even in fresh water. They, above all seaweeds, are responsible for the fouling of the bottoms of ships, producing what is termed "grass" by sea-going men.

MAGNIFIED TIP OF A FROND OF FEATHERY PTILOTA, A RED ALGA, SHOWING FRUITS ON ITS MARGIN

Another group, the *Fucaceæ*, of the brown algæ occur in all seas, but the species differ according to the temperature of their distribution. The thallus here is not so generalized as in some, and may present a distinct differentiation into such parts as stem, leaf and root, if these terms are permissible in connection with sea-weeds. The layers of cells resemble those of land plants in suggesting an outer layer of epidermis, with parenchyma beneath, and a central portion which is like that of vascular bundles The central strand passes along the plant into the stalk of the leaf, where it divides. The whole plant is attached at its root by a disc or sucker, or by special fibers still more suggestive of roots, and especially like the roots of parasitic plants In some species special branches are set apart to carry the reproductive cells, or these may be on the ends of the leaves, or they may be dispersed over the mass of the plant Where sexual cells are formed they are set free at ebb-tide as the result, in all probability, of the loss of water pressure, the cells uniting in the water when once more floated by the returning tide. Other forms are hermaphrodite.

Another group distributed in all seas, but especially in the North Atlantic, are the *Chordariaceæ*, which may be recognized from their slimy mass Usually they are in the form of strands, covered with filaments.

Next we may note the widespread *Rhodophyceæ*, or red algæ, with varying shapes and sizes, ranging in color from bright red to dull brown, and in appearance from filaments to flat bodies. One of them produces the well-known Ceylon moss from which is prepared a substance termed "agar-agar", which is of immense value

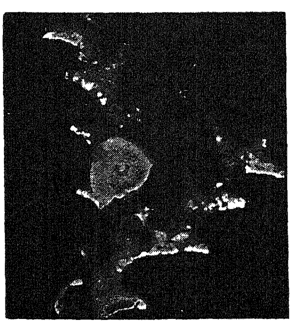


TANGLE OR FINGERED LAMINARIA LEFT EXPOSED UPON THE ROCKY SURFACE OF THE SEA-SHORE BY THE RECEDING TIDE

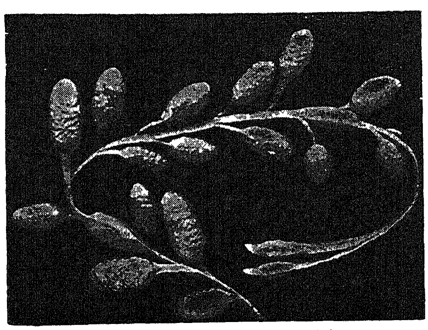
to the bacteriologist It has the property of solidifying liquids, in the same way as does gelatine, but agar-agar requires a far higher temperature than does gelatine to melt it, and hence can be utilized for growing such microorganisms as grow best at the temperature of the mammalian blood A peculiar family of this group are the *Corallineæ*, easily recognized from the fact that the thallus is encrusted with lime salts, producing masses like stones. Some species grow along with true coral, and act as a cement by joining the corals together Naturally they are very brittle. Several species may be found on American shores.

A remarkable group of sea plants called the Sea Grass must not be omitted. They resemble ordinary land plants much more closely than those already considered, especially in the fact that they have stems which dip down into the mud and are fixed by definite root fibers. From the stems there arise a number of extremely long, ribbon-like leaves, narrow and almost erect, being kept in position by the water The grass wracks are found growing in large masses between the high and low tide levels. Many of the sea wracks are brown and leathery, and may be contracted into a stalk below, by means of which they attach themselves, widening out above into flat, leaf-like structures. Such are the Laminarias, brown algæ of the North Sea. It may be noted, in passing, that no matter how like a land plant a sea plant may be, it never develops true woody tissue, no matter what its size.

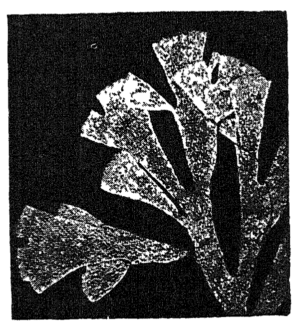
The sea plant remains stationary in its watery depths, or is swayed to and fro by the currents around it, but these do not tend to damage it, and no special contrivances are necessary to strengthen the plant, such as those we discussed in connection with trees of the forest. It is for this reason that aquatic plants, when brought into the open air, quickly collapse, their moisture evaporates readily, and,



SHELL ON SEA-FIR

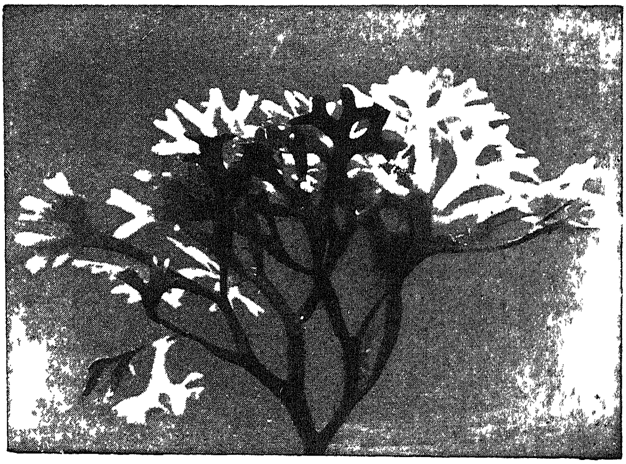


FRUIT ON KNOTTED WRACK



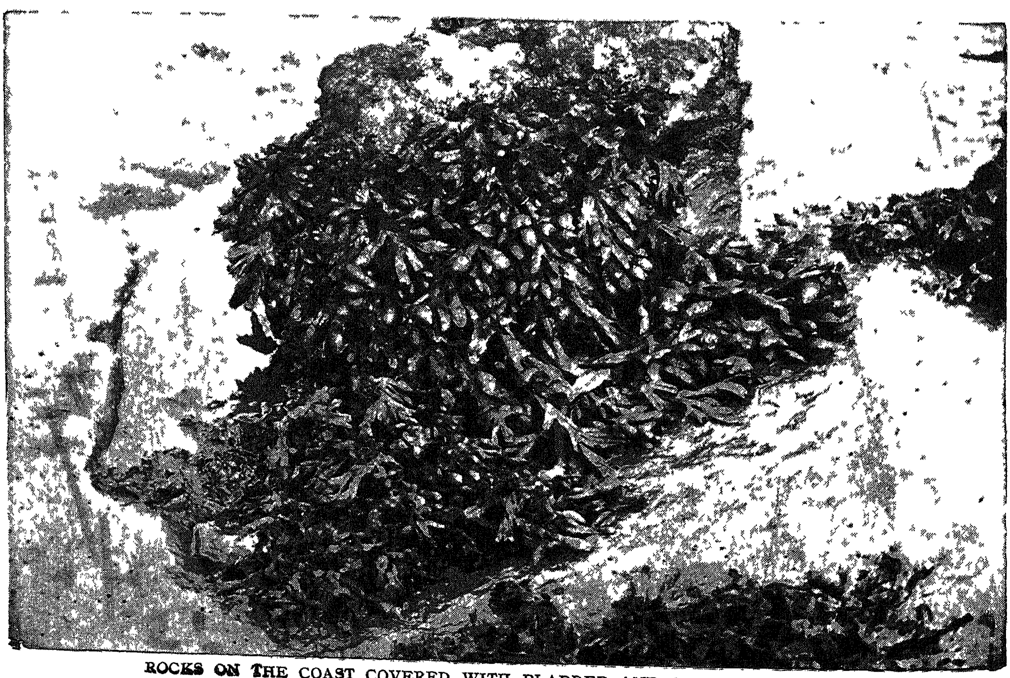
SQUARE-TOPPED SEA-MAT

having no hard framework, their characteristic shape — and with it their beauty — disappears. Their erect attitude in the water is assisted by the presence of air spaces in their tissues. The sea-wracks do not shrivel up between low and high tides; they simply lie flat until the water returns, but they can only stand this exposure for a limited time. The largest sea-wracks may grow to immense sizes, as much as from 300 to 900 feet in length, a prodigious growth comparable to the largest trees. It must be remembered, however, that these do not grow erect to this height, but grow at an angle towards the surface, taking the direction of the prevailing current.



CARRAGEEN, OR IRISH MOSS

The careful reader, who has followed us through our study of the plant population, alike of the earth's surface and the ocean's depths, will, it is to be hoped, have realized that the great lesson to be learned, from a rapid glance at the main points of an enormous subject such as this, is that plant life, like all organic life, has developed by natural selection and the survival of the fittest, until there have been evolved marvelous adaptations for specialization of function of which in the course of our studies we have seen so many examples. No such study has been effective if it fails to impress us with the wonders of creation and the beauty spread about us in such profusion by the Creator.



ROCKS ON THE COAST COVERED WITH BLADDER AND OTHER SEA-WRACKS

THE CARE OF THE SENSES

Practical Hints on the Preservation of Comfortable Sight and Unimpeded Hearing

THE CHEAPNESS OF SOUND TREATMENT

BEFORE we pass on to the health and happiness of the mind, there is one part of the bodily structure, and that the nearest to the mind, which we must specially consider — namely, the organs of sense and their working. We talk much of "exercise", but by that we never mean anything other than the exercise of the muscles. Yet the senses are infinitely more characteristic of man than are his muscles, and far more important for his happiness and efficiency, and they, too, may need exercise, and certainly need care.

This is, in large measure, a question of those concerned with the education of the young. The adult is, in this respect, fairly well "done for" — at least, as far as actual development of the senses is concerned, though it is still his duty to take care of what he has. But childhood and youth offer opportunities for the educative exercise of the senses such as were totally neglected in the systems of the past, and are only now beginning to be recognized as clearly in our own day as they were by the ancient Greeks.

The increased interest in music of sensible type, such as folk-songs, the revival of dancing, and other natural and healthy forms of rhythmic movement, the use of nature lessons, of open-air excursions for botanical or geological or definitely artistic purposes — these are examples of a new interest in the education of the senses, such as certainly will make their use more enjoyable in after years, and most probably also make their future health more stable. While care of the adult's own senses is mostly a matter of "medical" precautions, the care of the senses in childhood must not be merely medical and surgical, merely negative and protective, but must also be positive, constructive and educative.

For practical purposes the care of the eyes comes first in importance, and it is exceedingly well worth while. If ever a stitch in time saves nine, it is here. The importance of the teeth in relation to the general health has been vastly underrated. So with the eyes. In each case a special department of the body, which is a whole, has been given over to a group of specialists, and the relation of their work to that of the general physician and hygienist has been largely missed. We are now getting truer ideas of the facts. Especially are we indebted to the clever and original studies made by Dr. George M. Gould, the distinguished American ophthalmologist, of what he calls "eye-strain". He regards strain originating in the eye as the source of most of the minor ills of civilized life. In his "Biographic Clinics" he has studied the lives of many distinguished men, such as Darwin, Spencer and Huxley, all of whom suffered from chronic dyspepsia, and has argued that, without knowing it, they were really the victims of eye-strain, which the attention of a skilled oculist and the provision of a suitable pair of lenses would have cured. We are sure that Dr. Gould's main contention is largely right. The reader who suffers from vague, shifting symptoms of headache and dyspepsia and malaise, whose internal machinery is properly active, and in whom no obvious cause of the symptoms can be found, would do well to consult an oculist.

The importance of seeking special advice in all cases of eye-strain

But expert diagnosis and prescription are required. Many young people, with long sight and bad headaches, are promptly cured by a suitable pair of glasses, which any reasonably competent optician can prescribe. But many more, and especially older people, who are not necessarily long-sighted, go to the optician or to the general practitioner for relief, are prescribed glasses, and wear them, without anything but, perhaps, increased discomfort.

Really delicate "refraction work", as it is called, needs very special training, and even very special apparatus. No one has these at his command who does not devote himself to the study of the eye. Part of the modern theory of "eye-strain" depends upon the fact that, in many people, what is called the "muscle-balance" of the eye is not perfect. In such persons each eye may be carefully and separately examined as regards its refractive power, and lenses prescribed accordingly, without any relief resulting. The fact is that, though the patient has not an actual squint, the two eyes are not just so perfectly balanced that the image of any object falls *exactly* on the corresponding parts of the two retinæ. In order to see properly, therefore, and to the full advantage of "binocular vision", the patient is all the time straining a little, so as to correct this faulty balance. He requires a special kind of lens, neither spherical nor cylindrical, but prismatic, in order to compensate for the error, and then he will be happy. But only the expert oculist can detect and remedy this condition. Many such oculists, in the past, have rather despised "refraction work" as mechanical, and have been content to leave it to be done, more or less well, by opticians and general practitioners, but now they are coming to see that this is a kind of work which is worth doing just as well as possible.

Our first advice to the reader, therefore, is that, when symptoms exist and do not yield to ordinary treatment, consultation with an oculist of standing may involve the best investment the patient ever made.

The eye originally designed for effortless vision at a distance

So much for this vague, dubious, but certainly important subject of eye-strain — the influence of faultily working eyes upon the behavior and comfort of the rest of the body. Now we may proceed to consider the health and durability of the eyes themselves — which in "eye-strain", so called, need not suffer at all, though they cause so much discomfort and disordered function elsewhere. It is not necessary here to do more than remind ourselves of the elementary fact that the normal eye is made for effortless vision at a distance, with an apparatus for occasional use whereby it can be focused upon near objects. The eye was made for him who hitches his wagon to a star, whose eyes are almost ever focused upon infinity. But civilization, as it proceeds, involves a steady abbreviation of the range of vision. The use of the eye for reading and writing has become dominant, and while this involves continuous effort for even the normal eye, it involves still more for the long-sighted eye.

There is no doubt about "eye-strain" in such cases, at any rate; and it is, of course, a refinement of cruelty, to say nothing of useless incompetence, to spend money and skill and time upon the "education" of a long-sighted child without somehow or other providing it with suitable glasses.

What is the significance of the prevalence of short sight?

Short-sightedness, or myopia, however, is much commoner than long-sightedness, or hypermetropia, and is certainly becoming more so. The use of the eye at short distances alters the shape of the eyeball, so that it becomes more suitable for near vision. Thus we adaptively make ourselves short-sighted. So much was noted in the discussion of the physiology of vision in earlier pages of THE BOOK OF POPULAR SCIENCE, and here it is our business to consider the implication of these physiological faults, for the hygiene of the eyes in childhood and adult life.

In the first place, if it be true that the short-sighted eye is the best for use at short distances, we must reconsider what may be called the purely medical estimates of the degree of ocular defect in the community. Thus, we are told that in one school in Philadelphia two-thirds of the children had defective vision, and that of the three-quarters of a million or so of school children in London "ten per cent have less than one-third of normal vision". What exactly do these alarming statements mean? They are largely quoted by a class of Eugenists, by sensational writers, advocates of political panaceas and so forth, in favor of the view that "we are going to the dogs as fast as we can". But if the eyes of the short-sighted man do not tire, if he never has a headache, if he can read or write for hours on end, daily, without any injury or strain, what exactly is the significance for him of the fact that perhaps he has "less than one-third of normal vision"?

The advantage under modern conditions of short, strong sight

That statement merely means that he does not focus very accurately beyond a certain distance. This may prevent him from recognizing a slight acquaintance across the street, or from seeing all the facial byplay at a theater, but that is all, and a pair of lenses will correct it when he chooses to use them. When we read that "in Germany Cohn finds that twenty-two per cent of the lower classes are short-sighted, or myopic, while fifty-eight per cent of the upper classes are similarly afflicted", we have to ask whether it is not perhaps a rather welcome affliction that enables a man to do his appointed work in ease and comfort, while his neighbor, who boasts of his "strong eyes", cannot read for an hour without the beginnings of a headache. Such terms as "good eyes", "strong eyes", "bad sight", etc., may be only too full of meaning, but they are commonly employed about nothing more vital than the mere shape of the eyes in question.

Hence there arise several questions which we may reasonably begin to think about, as, for instance, what shape of eyeball is best fitted for civilized life? How is that shape of eyeball to be best attained — *e.g.*, by what kind of discipline or employment during school life? What shape or shapes of eyeball can legitimately be called normal?

The absurdity of assuming national degeneracy because of short sight

Is the vision defective, or an "affliction", which can be used at a few inches for hours on end, but is uncertain about the identity of people across the street? Or is that defective which requires no glasses at the theater or in the tennis court, but brings on a headache with half an hour's reading? The upshot of these inquiries is that the natural state of the eyes of our school children is not nearly so bad as the alarmists make out, and they only spoil the excellent case for attention to real disabilities by talking of "national degeneracy", because there are many children in the schools with eyeballs rather too long or too short from back to front. Doubtless there always have been such children.

Of course, it is impossible to prescribe suitable glasses for any pair of eyes until they have been individually examined, but certain general observations about glasses may be usefully made here. Short-sighted people, without special cause, do not require to wear glasses. Their health, and that of the eyes, does not suffer if they use no glasses — it being assumed for the moment that the two eyes are similar, and the muscle-balance perfect. But while the person who has no refractive error but symmetrical short-sightedness need wear glasses only for the sake of clearer vision at a distance, the long-sighted person must wear glasses for near work if he is to be comfortable. The disfigurement produced by the glasses may be objected to, but it cannot be helped. So much for the simple cases of both short and long sight.

A usual reason why people with short sight should wear glasses

But directly the case is complicated, as it very often is, even the short-sighted person should use glasses. Thus, in many people the two eyes are not exactly of the same

shape. If the disproportion is great, one eye will eventually not keep up with the other, and the two will no longer function together. The "fixing" eye proceeds to focus upon the object looked at, but the other eye remains unmoved, resulting in a squint. If eyes of unequal shape are to be used perfectly together, without strain, glasses, in which the lenses are of unequal strength, must correct the disproportion. A most significant reason for supplying glasses, even to very young children, is to give the less fortunately shaped (commonly and mistakenly called the weaker) eye a comparable efficiency so as to equalize the vision of the two eyes. Parents do not care to put glasses on small children, just because they on occasion are observed to squint, but this may be the truest kindness in the long run, from the standpoint of eye health and appearance.

The lenses must be properly made and so fitted in the frames that the center of each lens comes just in front of the center of the corresponding eye. The optician must, therefore, carefully measure the exact distance between the two eyes and supply the correct frame accordingly. Eye glasses should not be persistently worn too tight, for serious ulceration of the skin may result as a consequence.

Artificial light should be as much like daylight as possible

Special questions regarding various artificial sources of light arise when we consider the care of the eyes. Often we have to use the eyes by artificial substitutes for daylight, and these substitutes vary widely in color, intensity of light, steadiness, heat and other characteristics. The safe rule to follow is that substitutes for daylight should reproduce its conditions as closely as possible, for there is reason to assume, on evolutionary principles, that the kind of light that will suit our eyes best is that to which they have adapted for ages past. Some day, especially with further research in atomic energy, we may be able to produce artificial light that will be practically identical with the ideal kind of illumination that is derived from the sun.

The forms of artificial light in present use may and do often contain ingredients unsuited to the eyes, and these need not necessarily be visible. They may lie above or below the visible spectrum and yet be potent nevertheless. Here is a very real source of possible injury to the eye, and it is a danger for which no arrangement of lenses can be of help. To maintain eye health we must have an artificial light containing in abundance the rays that most stimulate vision, and, for the rest, a fair amount of bluish rays but a minimum of the hot red rays.

Daylight is the ideal light because it is diffused and steady

Two most important characteristics of daylight are, first, that it is diffused, and, second, that it is steady. The steadiness is most valuable, and in this respect electric light is as great an advance and advantage over gas light as the latter was over the candle. Observe that we have not referred to sunlight, so absolutely necessary for many purposes, but to daylight as the best light by which to use our eyes. Daylight differs from sunlight in that it is the sun's rays reflected from clouds, dust particles in the air and so on, thus coming from a diffused surface. Artificial light should be similarly diffused, so that we cannot tell from where the light actually comes, as is usually the case with daylight. For interior lighting sufficient light should be provided to give the necessary amount of illumination, and lighting units should be designed and placed so as to make the illumination reasonably uniform, without glare. A soft light does not hurt or fatigue the eyes, and, other things being equal, the softness of a light is directly proportional to the total amount of surface from which this particular light is derived.

Eye efficiency under different systems of lighting

The American ophthalmologist, Professor E. C. Ferree, after exhaustive tests to determine how different kinds of light affected the human eye, reported: "Our tests show that the eye loses practically

nothing in efficiency as the result of three or four hours of work under daylight. It loses enormously for the same period of work under a system of direct lighting, and almost as much under a system of semi-indirect lighting. Under the indirect system the eye loses but little more than it does under daylight, but not nearly so much as under the other systems of artificial lighting." A naked arc lamp causes such contraction of the pupil that we only employ a small fraction of the light offered. The waste, in terms of money and health, is obvious. Light of a similar intensity, due to an incandescent lamp, is utilized to double the extent, for the pupil contracts so much less.

The modern need for toned light rather than for brightness

Nothing fatigues the eyes so much as the arc lamp, as has been proved by noting the duration of "after images" produced by various kinds of light of equal intensity. The modern indirect lighting system has overcome most of the disadvantages of artificial lighting. Commonly, one or more lamps are pocketed in an opaque bowl, preferably provided with individual reflectors, and the light thrown against the ceiling and upper walls, from whence it is reflected and illuminates the room with a well diffused light, which is practically as harmless as natural light. The semi-indirect system employs bowls of translucent materials, but if the full benefits of truly diffused lighting are to be obtained the direct transmitted light must be limited so as to be but a fractional part of the diffused reflected light.

We see, then, that light should not be too bright, and it should also not be too faint. But the tendency nowadays, when electric incandescent lamps are so cheap and powerful, is rather towards the use of too much light than too little.

The walls of our rooms should be simply covered, for choice without patterns. The green of nature is restful and beautiful, and we can safely reproduce it nowadays in our rooms without fear of arsenical poisoning. Dead white we shall use with care; all that glitters is bad for the eye.

Practical hints for the use of the eyes when reading or writing

When we sit down to read or write we shall habitually observe certain simple precautions. We shall not sit facing the light, but with the light coming over either shoulder if we are reading, and over the left shoulder if we are writing. The light, of course, will be "soft", strong enough, but not too strong, diffused, steady and as nearly the color of daylight as may be. Neither in reading nor writing should the head be too pendant. This error is difficult to avoid, but it must be avoided by those whose eyes give them any trouble, whose eyelids tend to become heavy, and in whom the conjunctiva, or lining of the lids, tends to itch or smart. Most of these troubles of the eye depend essentially upon congestion of the conjunctiva with blood; and just as we raise a limb in which the veins are varicose, so we should not drop the head, thereby calling in all the power of gravitation to prevent the proper return of the venous blood from the delicate capillaries of the conjunctiva.

Those who use their eyes very hard at short range do well to give them intervals of rest occasionally, thereby giving the ciliary muscle, so continually employed in the act of accommodation, what we may call a "breather".

The advisability of giving the eyes rest by change

The eyes may be shut, or we may look out of the window at the landscape (which involves relaxing the accommodation), or we may even look at landscape paintings in a room, an act which has the same effect. But, as regards the infant and the child, such warnings and advice are out of place, for the simple reason that there should be no such continuous use at short range to be relaxed. The eye of the infant and of the child is normally long-sighted. The proper work of a young child is its play — the right kind of play, involving the use of the eye at the range for which it is suited. The time will come soon enough when the eye has to be used at shorter range, and the length of its axis will be adaptively modified.

There is much to be said and done about the details of reading. Strong arguments exist in favor of the use of black paper for books, with white ink, thus affording the eye rest everywhere, except where there is something it wishes to see. At present, of course, the eye is stimulated and worked by everything but the letters. Type should be large, solid. Letters should be as unlike one another as possible, and their form should be clear-cut and without superfluities. The form of the German letters is regarded by many German authorities as largely responsible for the extreme and increasing short-sightedness of those who are compelled to read them.

Let the eye be attended to in time. Danger is so easily averted, and damage is so difficult to repair. If a really skilful dentist is worth far more than his fees, so is a really skilful oculist.

The dangers of inexpert treatment of the eye

Confident ignorance and half-knowledge do terrible harm here, and glass eyes are not nearly so useful as false teeth. The optician or the general practitioner may be right nine times out of ten in his prescription of lenses, but the tenth time he may be wrong. He may drop atropine into an eye which he wishes to examine further, and in the hope of doing good, with the result of precipitating an attack of glaucoma, which will ruin the eye forever. When it comes to dropping atropine into eyes, the expert is the man to consult. Many a blind man, blinded irremediably by glaucoma, would be seeing today if neglect to consult an expert in time had not ruined his eyes, or if the pressure within them, already too high, had not once been fatally raised by drops of atropine, which dilate the pupil, bunch the iris together in a mass which prevents the fluids of the eye from circulating properly, and so raise the pressure to a point at which the retina lays down its task, without repair. On the other hand, if cases of incipient glaucoma are seen in time a delicate and simple operation will relieve the pressure, at the cost of a snippet of the iris and will save the sight.

By far the commonest of all causes of blindness is, however, of a different order. It is due to infection by a minute microbe known as the *gonococcus*. Practically never does this microbe attack the eye except in one instance, which is at birth. As many a baby opens its eyes to the light for the first time, it receives the infection which will shortly blind them forever. This unspeakable abomination occurs every day in every civilized country, and it is entirely preventable.

No doubt the infection should not be present. But even if it is, the eyes can still be protected; and though the *gonococcus* be absent, other microbes may very likely attack the delicate eyes of a baby.

The terrible results of inattention to the eyes at birth

The rule is therefore absolute, admitting of no exception, in the palace of a king or the hovel in any slum, that the eyes of the new-born child, within a minute or two of birth, and as the most essential part of the business of washing the child, shall be separately, slowly, repeatedly swabbed out with a liberal supply of a mild but active antiseptic. Weak solutions of the salts of silver are often used for the purpose, about as good as any to which a precious metal may be put. Regulations in this respect should be, and in some states are, enforced by law.

The general estimate is that not less than one-third of the blind inhabitants of any civilized country owe their misfortune to neglect within the first few minutes after birth. They are usually described as having been "born blind", but that is not true. They were born seeing, with normal, perfectly formed eyes, and they were then blinded. The intense inflammation produced by the *gonococcus* leads to destruction and ulceration of part of the cornea. In due course this heals, but the scar is opaque. The eyes are imperfect at birth: the macula lutea is not distinct; the lens is nearly a sphere, which grows less spherical in adult life and in old age becomes flattened. The lachrymal glands for a time do not secrete tears, and the eyes do not coordinate perfectly until the age of three months.

The curse of noise and the soothing power of music

The only other sense which requires our consideration here is the hearing. As we have already observed, modern urban life imposes specially severe burdens upon this sense, with penalties which show themselves partly in disturbed and dreamful sleep, and partly in the consequences of imperfect ventilation, for we are constrained to shut out air in order to shut out sound. Citizens of the next generation will be much more careful to keep their cities quiet. At the other extreme from noise, with its harmful influence, is music, the hygienic and therapeutic value of which has been believed in for many ages, and about which much might be written. Music of the right kinds, rightly employed, has a healing and soothing power, as well as possibilities of exhilaration not lightly to be discounted. Music is preëminently the social art, as has often been observed, and as the history of its evolution proves. Hence we may well expect some help from it in the care and treatment of the insane, who are typically a-social — not necessarily anti-social, but simply not social. And that is what we find. Only the very worst cases in any ordinary lunatic asylum fail to respond to, and even be partly made social again by, the bond of sympathy and of common interest which music affords. In all modern asylums music is freely provided, as a really therapeutic measure.

The insufficient investigation of the ameliorative influence of music

Experiments in the therapeutic use of music were made in general hospitals some years ago, without notable results. Such experiments, repeated with our present knowledge and in direct relation to nervous and mental cases, would repay any investigator today, when so much more is being learned about the psychical side of disease. Nearly all of us have been helped by music, as Saul was by young David's harp. Of course, there are morbid and healthy kinds of music, as of all forms of artistic product. One does not necessarily mean that the ill or weary or depressed are only to hear jolly, happy music. There is a noble sorrow — the sorrow of noble men for noble objects; and such sorrow, as expressed in the music of Bach or Beethoven, may be much healthier in its influence than the wild joy of some other composers.

The structure of the aural apparatus demands due care, no less than that of the eye. No one allows a quack to operate upon or manipulate the structure of the eye, because everyone knows how delicate and complex an organ that is. Unfortunately, the aural apparatus is invisible, except for that sound-catcher which we call the ear. But when one has seen the middle and internal ear, one is as likely to tolerate the ear quack as the eye quack.

Of course, the layman is not in a position to judge of the real skill of those whom he consults, though clearly a specialist or a surgeon who works at an ear hospital is likely to be properly qualified. But at least the layman can have the elementary sense to go further, rather than be content with the man who treats the ear without examining it by means of a good light reflected from a mirror into the external canal, so that the drum can be seen.

The crime of failing to prevent after-effects of childish ailments

Just similarly the layman will be wise to mistrust anyone who professes to deal with his eyes without using the ophthalmoscope, or to prescribe for chronic hoarseness without using the laryngoscope.

"Artificial drums" for the ear have been repeatedly tried in vain, though mere simple pellets, such as aural surgeons use, may do something. The best course is *not to let the drums be pierced by disease.* Practically never need this happen. If cases of scarlet fever were properly looked after, if adenoids were dealt with, if the pernicious delusion that measles is "only measles" were dispersed, then infection would not reach the middle ear from the throat at all and there would be no pierced drums to deal with.

The acute infectious diseases are most frequently contracted during the early years of school life, and hence the first effort of

the medical inspector should be the detection of these diseases. The eruption upon the skin is frequently the first noteworthy symptom, and this may be unobserved or disregarded by the parents, and it is therefore not strange that they should carelessly send the child to school, if he or she is not ill enough to be kept in bed.

Though the larynx is not a sense-organ it is closely related to sensation, and the throat is common both to the ears and to the larynx. A few words may therefore be said here as to the hygiene of the voice. In the presence of adenoids or of enlarged tonsils, or a polypi in the nose, or a deflected nasal partition (between the two nostrils), the larynx is always liable to give trouble—the general congestion in the neighborhood spreads to the vocal cords, causing hoarseness, "hawking", and even loss of voice. The larynx cannot be seen without the aid of Garcia's mirror, the laryngoscope. No one, therefore, whose larynx is troublesome should be satisfied unless this mirror is employed by his doctor. If it is not used the larynx is not seen, and if it is not seen it should not be treated.

The care of the voice is another question, for which no laryngoscope is required. The inhalation of tobacco smoke has been already discussed. For the rest, let the voice be used in its lower register. Half the secret of having a voice that lasts, and is pleasant and clear, and the use of which is unattended by fatigue, is to keep the vocal pitch low. King Lear described Cordelia's voice as "soft, gentle and low, an excellent thing in woman". The shrieking which distresses the ear also hurts the organ which produces it.

Clergymen are particularly prone to over-use of the voice, *plus* abuse of it, owing to the employment of an unnaturally high pitch for reading and preaching, and "clergyman's sore throat", or chronic laryngitis, is the consequence. For this malady, rest alone is the sovereign remedy.

Chronic hoarseness should never be ignored. Once its cause is definitely known, there may be little to be done, but no victim of this complaint should be content until at least the cause has been ascertained. He may please himself as to whether he will stop inhaling tobacco, whether he will have adenoids removed, or his nose cleared out. But there are other conditions of which chronic hoarseness may be the symptom. It may indicate nervous disease, or the presence of an aneurism, or enlarged artery in the chest. Again, the hoarseness may be due to a wart or other growth, which can easily be removed, and the voice perfectly restored. Finally, if the growth be of a malignant character, modern surgical methods will often avail to extirpate it entirely and save the patient's life, if not his voice, provided only that, as but rarely happens, the surgeon sees the case in time.

HOW COLD CONQUERS DECAY

Man's Constant Battle with Microbes
for the Preservation of His Daily Food

THE TRIUMPH OF REFRIGERATION

IT is doubtful if anything has affected the economic conditions of our country in recent times so much as the discovery of means of preventing the decay of food-stuffs. Next to the railway and the steamship, the refrigerator has perhaps done more than any other modern invention to benefit our vast industrial population. Indeed, without the new methods of sterilizing, chilling and preserving meat, butter, fruit, vegetables, fish, milk, eggs, that are now practised, our cities could not properly be fed. Extreme fluctuations in the supply and price of the principal provisions would be frequent, and a large number of the poorer classes would be subject to recurring periods of misery. But on the foundation of a few simple inventions a magnificent industry has now been built, by means of which foods produced in localities where there are insufficient people to consume them are carried and delivered in a fresh condition to hungry and overcrowded cities, or delicacies that will grow in one climate are preserved for the enjoyment of less fortunate lands.

And all this is the result of an easily won victory over the germs of decay. The microbe is a useful scavenger. But for its incessant and universal action our earth would be buried in the ruins of life. Everything that died would rest on the ground, encumbering and stifling all the younger growth of our planet. Forests would be but a mass of fallen trees, through which no young, green shoot could pierce. Fields would be blanketed with dry, withered grasses and dead plants; and even the flesh of the mammoth of the great Ice Age would not have perished yet from off its bones. It is the microbes that clear all the dead growth from the earth, and keep a large, clear path for succeeding generations of plants and animals. It would be disastrous to interfere on a large scale with the work that they are doing, but from the earliest dawn of civilization man has been compelled to fight them continually for the preservation of his food supplies. Every time that he has tried to store the abundance of one season against the need of a time of scarcity, he has had to fight against the innumerable germs of decay that fill the air with their invisible armies, and occupy all the seas and lands between the ice-bound region of the poles.

So, from the earliest ages, the hunting savage has dried and smoked and salted his meat and fish. Pastoral races have found a way of preserving the milk of their cattle by making it into butter and cheese; farmers have discovered a means of preventing their grain from rotting by keeping it from becoming moist; and housewives have learned to pickle certain vegetables, and make sugary syrups to conserve fruits. Drying is the most natural and oldest process of preservation. In nature, the germs of seeds and nuts are protected from the agents of decay by their dryness. The microbes that bring about decomposition are a very low kind of plant and, like all vegetable life, they need moisture to grow and multiply. So by drying meat the Boers make their biltong, and the Indians their pemmican. And several great modern industries use the drying process in making extracts of meat and preparations of evaporated milk, which can be kept for a long time.

The preservation of food by drying is called dehydration, because most of the water contained in the food is removed. (*Hydor* is the Greek word for water.)

Sun drying is still one of the favorite methods of dehydration. The fruits and vegetables that are to be treated in this way are washed, peeled and subjected to steam; then they are set out in the sun to dry. The process generally takes several days.

Dehydration by spray drying

Foods like milk and eggs, which contain large amounts of water, are dehydrated by a method called spray drying. They are sprayed through a nozzle into a vacuum chamber, and in this chamber they strike a hot plate or cylinder. This causes the water in the foods to evaporate quickly; the solid constituents adhere to the plate or cylinder and they dry in the form of a powder. This powder is scraped off and put into packages. Foods are also dehydrated by means of heated air. The food is set on trays and put in an oven; hot air is then blown through the oven. Food that is prepared in either one of these ways is nutritious enough, but is generally not so palatable as it was originally.

The use of dehydrated foods in World War II

A great deal of dehydrated food was sent overseas in World War II at a time when shipping space was at a premium. Obviously foods like milk and eggs occupy much less space when they are dehydrated than when they are in their original form.

Meat and fish may be very effectively preserved by smoking. The preservation of food in this case is due partly to the drying action of heat and partly also to the antiseptic action of some of the substances, such as creosote, of which the smoke is composed. Among the best woods for the production of smoke for preservation purposes are hickory, beech, birch and poplar. The meat is sometimes smoked first at a moderate temperature for 24 hours, then for a short time at 212°; sometimes it is smoked throughout the process at an extremely high temperature In both the slow and rapid methods, the smoking is continuous.

One of the oldest methods of preserving food is the use of a chemical with antiseptic qualities. Some of the "chemicals" involved are familiar substances like salt, sugar, vinegar and spices

Salt is one of the most effective of such preservatives; it is an effective germ-killer and yet it is healthful to the human system if it is used in moderation It is employed only with foods, like fish and beef, whose flavor is improved by the addition of salt. Sugar is another food-preserving chemical In the case of preserves, jams and jellies, the fruits and their juices are first sterilized by boiling; enough sugar is then added to make sure that the bacteria that are responsible for fermentation cannot thrive Vinegar in pickles produces much the same effect.

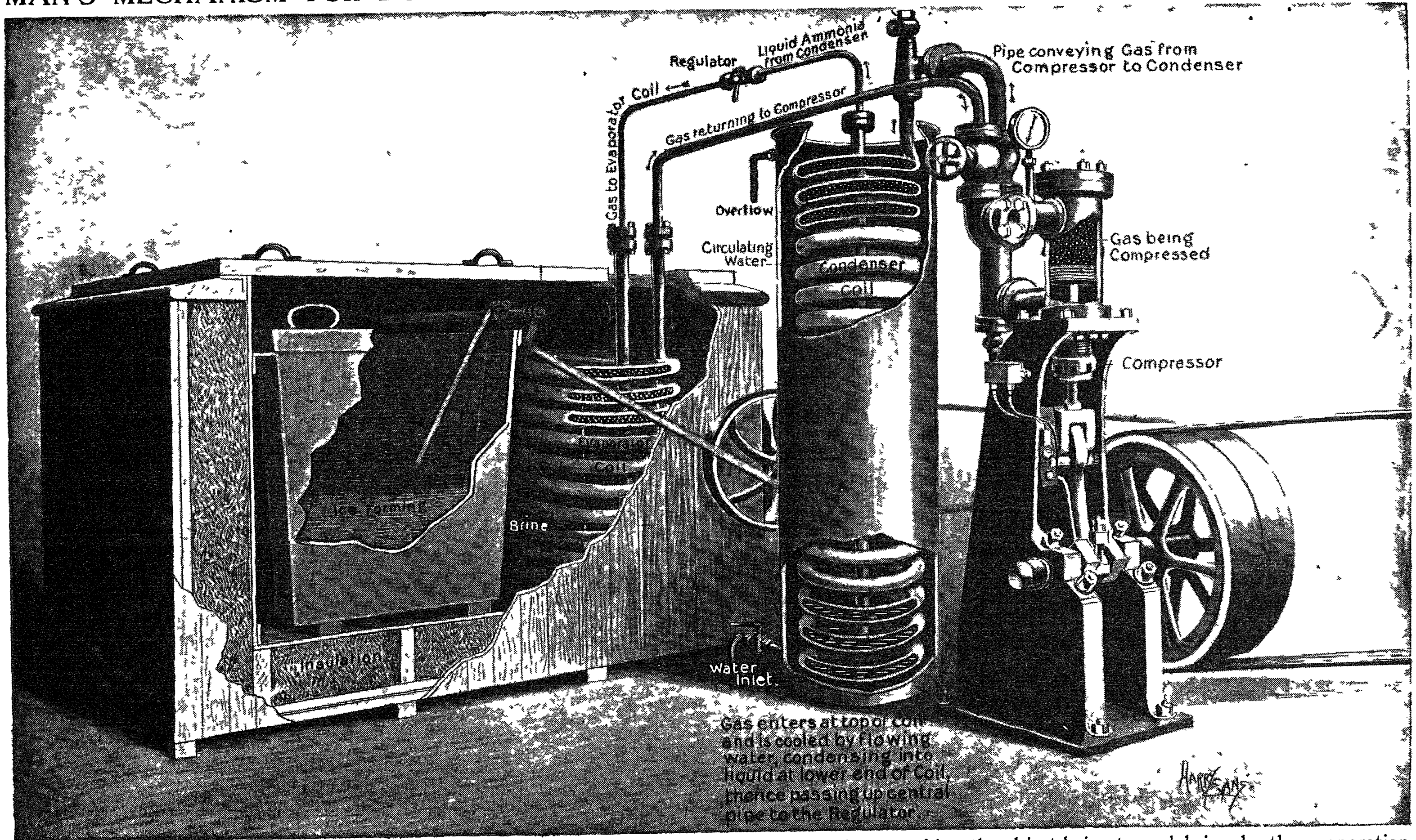
Some chemicals used for food preservation may be harmful

Certain chemicals used in the preservation process are harmful to man when they are taken in large quantities. These include boric acid, salicylic acid, formaldehyde, benzoic acid and potassium nitrate. They are used in such small amounts in the preservation of food that they are generally not harmful; but they occasionally interfere with the proper functioning of the digestive organs. The use of such chemicals is carefully regulated by law.

Appert discovers a new preservation method

A popular method of food preservation is to sterilize the food by means of heat and then to cover it in such a way as to keep the air out. This method was first employed for the preservation of meat by a French inventor, François Appert, at the time of the Napoleonic Wars. He put the meat in glass and china jars. These are excellent materials for the purpose, but, of course, they are breakable. It was not until the invention of the machine-made tin can in the United States that the method of sterilizing food and then putting it in a hermetically sealed container was widely adopted.

MAN'S MECHANISM FOR DOING THE ICE-WORK WHICH WINTER CAN DO SILENTLY IN A NIGHT



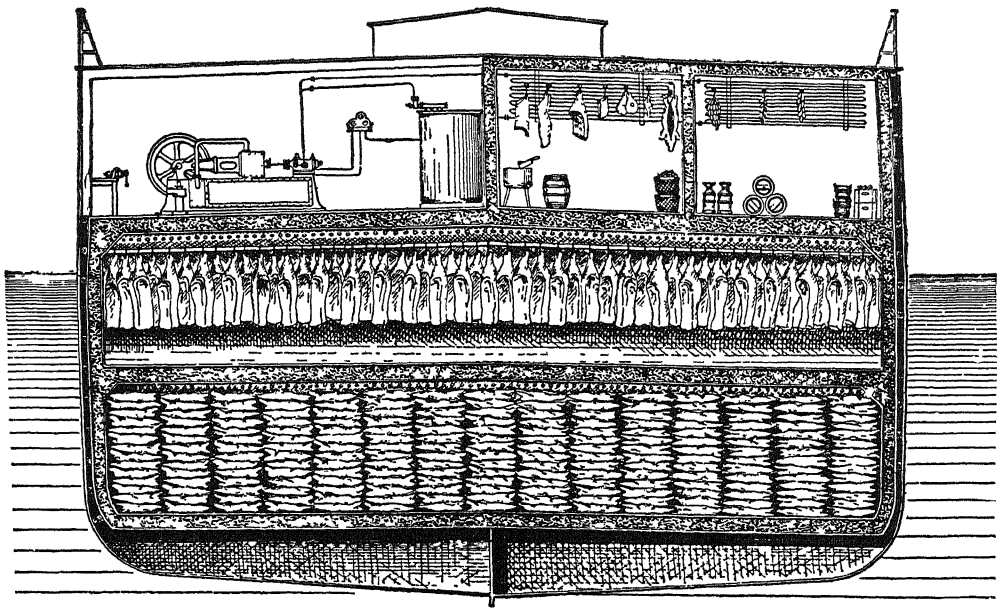
This picture-diagram shows the principle of the refrigerating machine, as applied to the manufacture of ice, the object being to cool brine, by the evaporation of liquid ammonia in coiled pipes, sufficiently to freeze the fresh water in a can submerged in the brine.

A considerable amount of serious and mortal illness has been traced to the eating of canned food. Ptomaine poisoning is sometimes attributed to the action of the acid of the sterilized food on the interior metal of the can. It is doubtful, however, if canned food can take up sufficient tin to produce any harmful results. It is more likely that the presence of the poison is largely due to imperfect sterilization. This is certainly a danger in the case of large tins which have been cooked carelessly or hurriedly. In spite of the high temperature of the steam-heated boiler, the can is not always subjected to the heat for the full time necessary to destroy all the germs. Some of the spores of microbes have a curious covering that enables them to stand extremes of heat and cold, and then grow and multiply when the process of sterilization is over. This is why a small tin of canned food is safer to eat than a large tin.

In other cases the food may have been tainted before the canning process — quite a possible thing in factories that only can the inferior parts of animals, under conditions that are not remarkable for cleanliness and for the scientific examination of the slaughtered beasts. But where the process of sterilization is carefully carried out, and especially where glass or china vessels are used instead of tin cans, there is practically no danger of the consumer suffering from ptomaine poisoning.

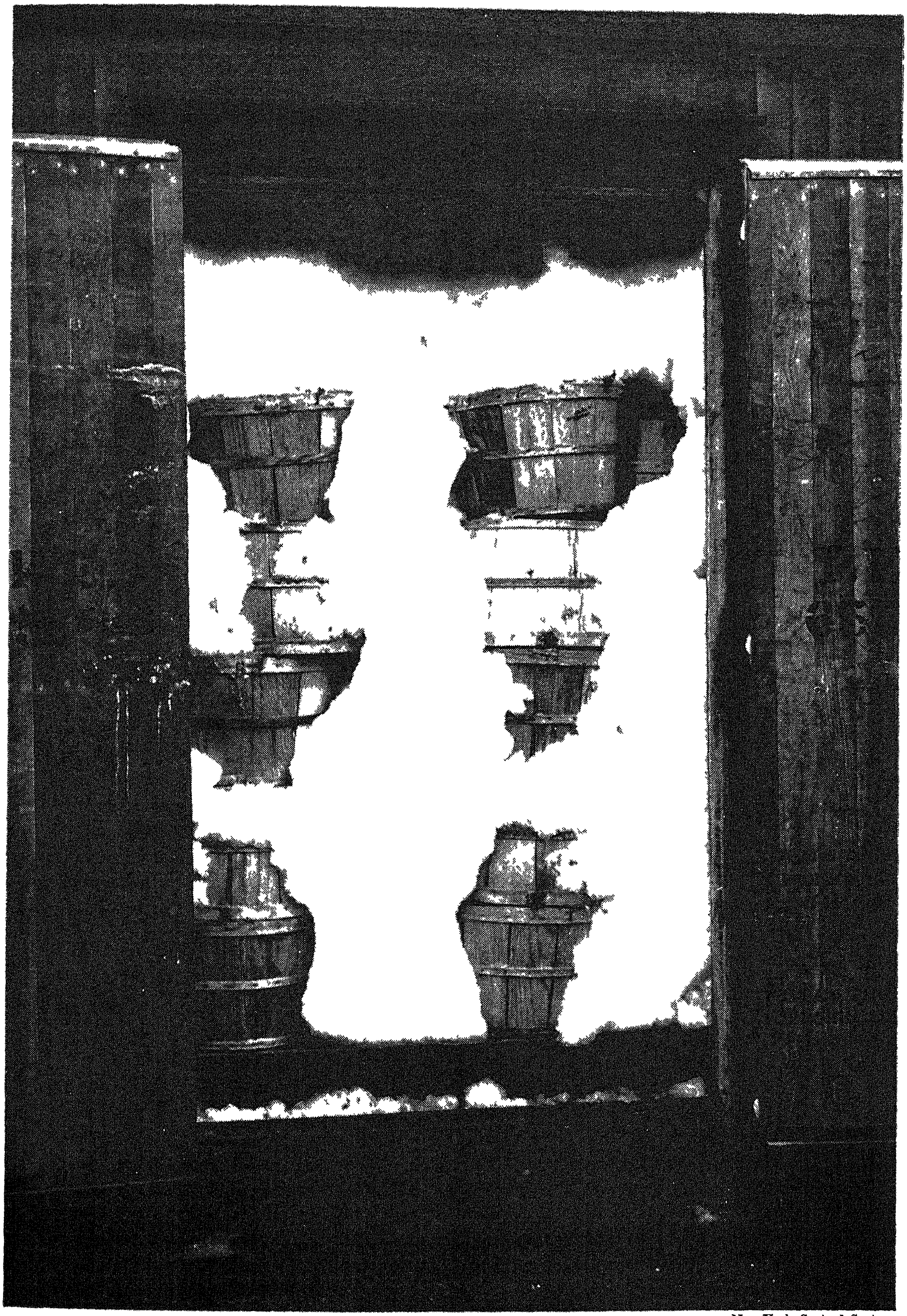
No risk, however, is run in eating food that is conserved by the latest method — mechanical refrigeration Although the youngest of man's allies in his fight against decay, this method is already by far the largest and most far-reaching in its applications, and yet in spite of the large numbers of cold storage warehouses, refrigerator-cars and steamships and artificial ice plants that are now in operation, this important modern industry is still growing by leaps and bounds. It now extends to almost every quarter of the globe and it provides adequately preserved food for many millions of people.

A good many people are still prejudiced against meat that has been kept for any considerable time in cold storage. But they eat and enjoy a good deal of it notwithstanding, some of it even grown on distant pampas. The fact is, cold storage meat if properly handled, is as pleasant to the palate and as easy of digestion, as though freshly killed nearer home.



Courtesy Kroeschel Bros

SECTION THROUGH A STEAMER EQUIPPED WITH CARBONIC ANHYDRIDE REFRIGERATING MACHINERY, AND USED FOR THE TRANSPORTATION OF MEAT



New York Central System

Fruit is kept fresh in refrigerator cars by packing crushed ice around the bushel baskets containing the fruit. After the cars are loaded, the ice is sprayed into them through a high-pressure hose.

The prejudiced attitude toward frozen foods arose partially from the fact that in the early days of the cold-storage industry there were some complete failures and many mistakes. Experimentation has solved practically all the problems presented by refrigeration. Frozen foods are now considered to be a highly desirable commodity; they include a great many different varieties of foodstuffs.

Main steps in preparing food for freezing

There are three preparatory steps in the processing of food before freezing that are basic for practically all types of foodstuffs. First, the products that are to be frozen are carefully selected by buyers. Secondly, they are inspected upon arrival at the factory and then trimmed of waste, cleaned and given any necessary prefreezing treatments. Finally, the products are packaged (if this is necessary) and then frozen.

The freezing process somewhat alters the nature of the products

Foods undergo certain definite changes upon freezing. Water, which is generally a high-percentage component of most foodstuffs, shrinks in volume until cooled to about 39° F., and then it expands again on cooling to the freezing point. While expanding it filters through the cell membranes of the organic material in question and fills the interstices, or spaces, between the layers of these cells. And there it freezes, with the result that crystals of ice fill out the interstices and squeeze the cells out of shape through the pressure of expansion. Great damage can be effected on organic tissues by these ice crystals, especially if the product is subjected to a slow temperature decline through the range between 31° to 25° F. Within this temperature range the large ice crystals that form puncture the cell walls of the product's tissues, with the resulting loss of cell contents upon thawing. The introduction of quick-freezing techniques in 1930 brought about a revolution in refrigeration methods, since foods could be frozen solid in a fraction of the time formerly required. In quick-freezing the temperature range where maximum-size ice crystals form (31° to 25° F.) is passed through rapidly; consequently, the resulting ice crystals are relatively small and harmless.

In frozen foods the bacteria of decay remain dormant

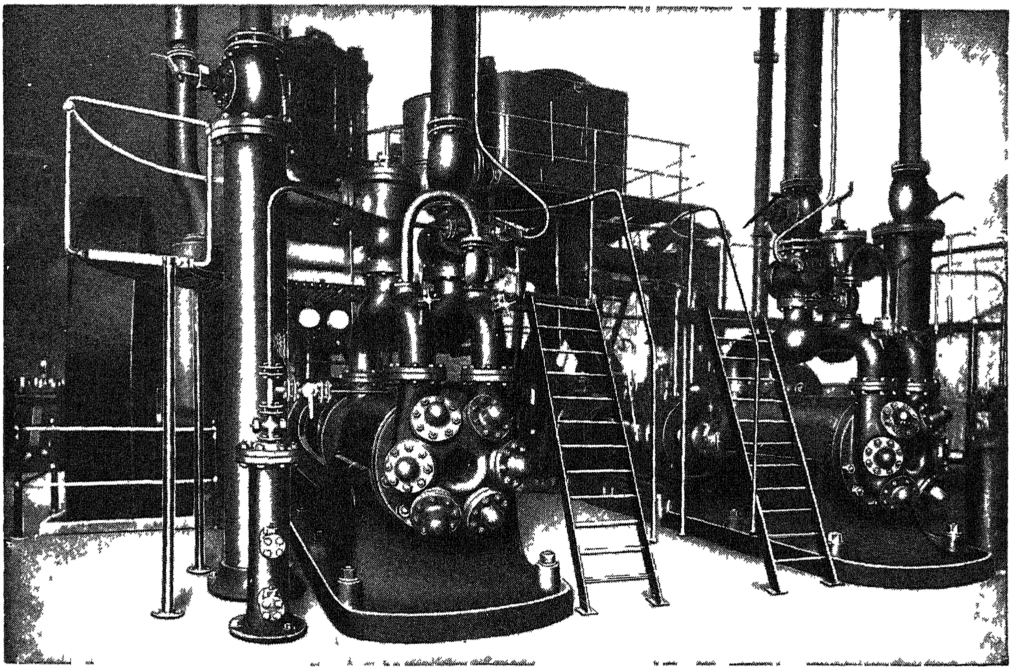
Frozen foods may be transported for thousands of miles from south to north, and through the tropics, without any harm befalling them, for all the ordinary processes of decay and decomposition are arrested. It is true that the bacteria of decay are often alive and present, but they are dormant, or inactive, as if they were hibernating. It is practically impossible to kill the bacteria by any practical method of refrigeration. They have been exposed to the temperature of liquid air (—192° C. or —314° F.) and yet thawed out alive. But it is sufficient that they cannot, at cold-storage temperatures, do in several months the damage that they could do in a single day on foods kept at an ordinary temperature. For all practical purposes their natural activities are frozen into harmlessness.

In the thawing process the ice crystals melt, and the water filters back into the cells, which resume much of their normal shape. The food products look and taste fresh, and only a microscopic examination of the cells can show that they have been squeezed by the ice crystals.

Frozen foods compare favorably with fresh foods

Most experts in the problems of quick-freezing and cold storage have agreed that generally there is no appreciable difference in chemical composition between fresh foods and foods kept frozen for considerable periods. If good-quality products are properly processed in the plant and promptly frozen, the nutritive value is almost as high as in fresh foods. As for poultry, it has been said that the changes in chickens in twenty-four hours on a hot summer day are far greater than those that take place during twelve months of cold storage at the temperature of 10° F.

In short, cold storage has no deteriorating effect on the condition of meats, poultry and fish for a period long enough to bridge over the time from one season of abundance to another. For every food substance there is a period of plenty, usually but a fraction of the year, when prices are low to the consumer and profits large to the producer. During the remainder of the year food is comparatively scarce, and consequently high-priced. It can only be cheapened and brought within the reach of all by refrigerating processes used in the transport and storage of fresh provisions.



A REFRIGERATING-MACHINE FOR MAKING 200 TONS OF ICE A DAY BY THE AMMONIA PROCESS

So every large increase in the use of modern methods of refrigeration tends to maintain a constant supply of food for the entire population.

Practically all parts of the dairy industries have been revolutionized by the modern refrigerator. The cooling of city milk, the cooling of separated cream, the cooling of water to wash butter, the cooling of butter stores and cheese stores and egg stores, are all best done with refrigerating machinery. In the successful manufacture of butter in hot weather, mechanical or ice refrigeration is essential. And pasteurized milk is now largely made by keeping it at a high temperature for twenty to thirty minutes, and then cooling it rapidly. By this means the flavor is preserved, and the milk will keep sweet for days. And, what is of more importance, the deadly disease germs, which spread from cattle to human beings through the use of fresh milk, are destroyed.

Another advance in healthfulness effected by the modern refrigerator is found in the new methods of ice-making. Artificial ice, when made by the latest methods, is much purer than natural ice. For the water is first distilled by boiling, and also freed from air, before it is subjected to intense cold. Yet the process is economical, by reason of the fact that the exhaust steam from an engine can be filtered and then distilled and used in making ice Various methods of agitating the water have also been developed to separate the air and other impurities, so that it is now possible to make good clear ice from raw water without the expense of distillation in plants where the condensed steam does not supply a sufficient amount of distilled water.

The principal feature of an ice plant is the tank room. Connected with this are the ice house for storage, the loading platforms and, at a distance, the boiler and machine room The methods used in ordinary cold storage are utilized here. In one method, brine is passed over the refrigerating coils, and then led into the ice tank; in the other, the liquid ammonia runs through pipes in the tank and in evaporating freezes the water directly. A hoist or crane above the tank lifts up the great blocks of ice and carries them away to a platform. But in some cases the blocks are sent down an inclined plane or runway into the ice house.

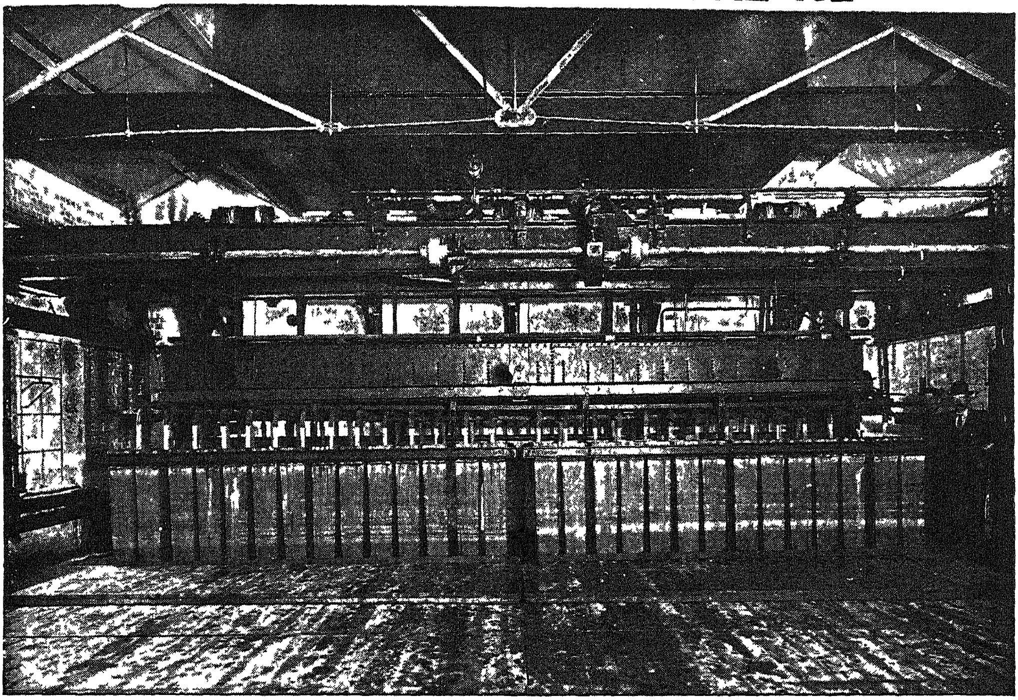
Then there are sometimes endless chains, provided with hooks that grab the blocks of ice and raise them from one floor of the plant to another. Circular saws cut the ice into smaller blocks, which then travel automatically down a conveying belt. Another machine breaks up great blocks of ice into small pieces under a pair of rollers that grip the ice slab with their steel points This is the way that small ice is made for fish dealers, hotel and restaurant keepers and for packing newly caught fish on trawlers. This small ice is also used in keeping fish for railroad transportation, in larger sizes it is employed on many refrigerator cars.

Like many other important inventions, the refrigerator is used in ways that its first inventors never dreamed of. For instance, refrigerating machinery is an essential part of air-conditioning equipment In the central-type air-conditioning system the water used for the spray is usually cooled by some means of mechanical refrigeration. Since a liquid requires heat to evaporate and consequently absorbs heat from its surroundings while evaporating, a cooling effect is produced through the vaporization (evaporation) of a liquid refrigerant. Thus in small installations, heat is removed directly from the air by the evaporation of refrigerants

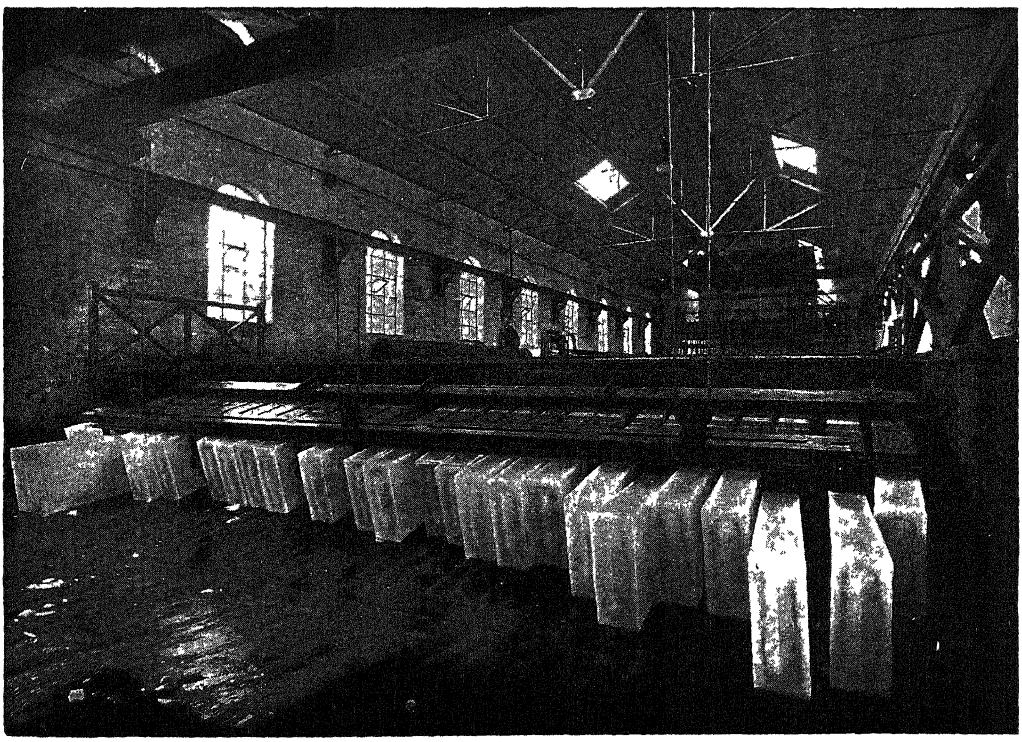
Torkel Korling

The rounded objects in the foreground are army-style hams hanging in the cooler of a packing house.

THE MAKING OF ARTIFICIAL ICE



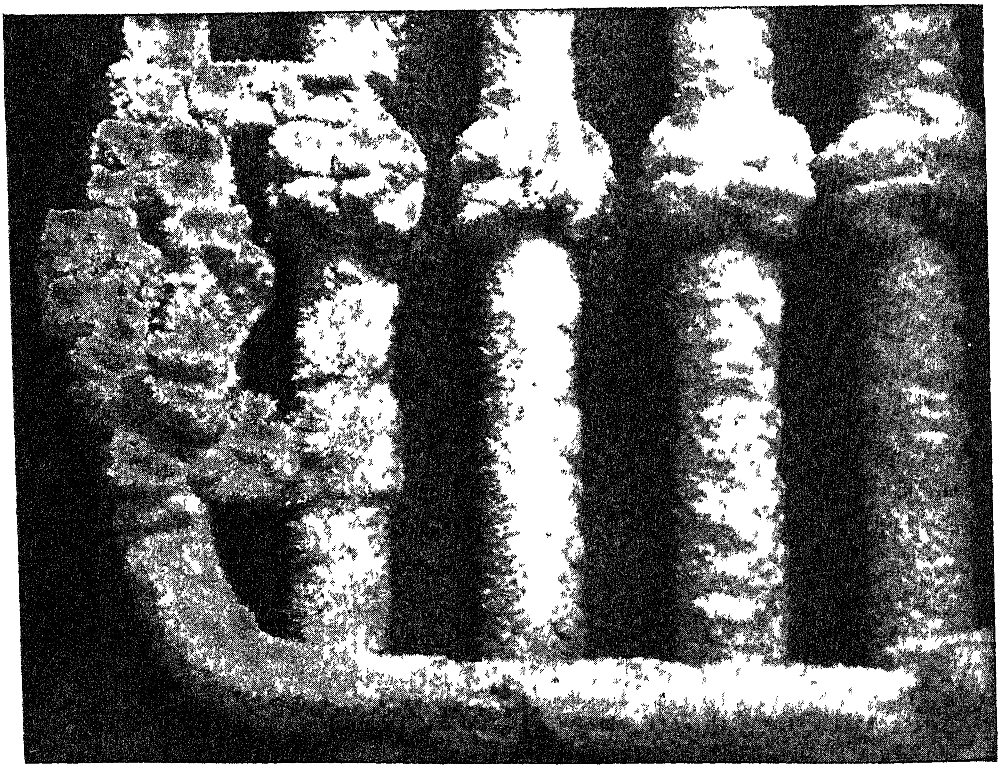
FILLING WITH WATER A ROW OF CANS IN WHICH ICE IS MADE BY REFRIGERATING MACHINERY



TIPPING A ROW OF BLOCKS OF ICE FROM THE FREEZING-CANS BY MACHINERY

contained in a surface cooler, which is established directly in the path of the air stream. Powerful refrigerators are also necessary in candle and paraffin oil works. Out of the oil they freeze the solid paraffin that is largely used in candle-making. This process is so important that the development of the paraffin industry dates from the time when a refrigerating-machine was used in the refining process.

Until artificial refrigeration was first used in 1882 in cooling chocolate, the manufacture of this article of food had to be suspended in the hot weather. The chief chocolate manufacturers now use artificial cold on a large scale, for it makes for more rapid production and fewer molds and much less waste. The modern brewing industry has been entirely built up on the refrigerating-machine, which enables operations to be carried on on a larger scale and with more accuracy than was possible under natural conditions. In tea-factories and soda-water works, refrigeration is also largely used; and in sugar factories and refineries concentrated juices are obtained by freezing and removing the superfluous water In india rubber works, artificial cold is necessary in cheapening the cost of manufacture, and permitting the material to be worked up in a better manner than was formerly possible In the manufacture of photographic accessories, gelatine and other substances are now usually cooled by refrigerating machinery; and the manufacture of dynamite has been made much safer by the same means



THE HOAR-FROST THAT COLLECTS ON THE PIPES OF A COLD STORAGE PLANT

The refrigerator has also been an important instrument of progress in many other industries, in which it would be impracticable to carry out certain processes in the hot summer months without some artificial means of cooling the material. Even in great constructive engineering works, where a water-bearing stratum is reached, through which it seems impossible to sink a shaft or drive a tunnel, a refrigerant is circulated through pipes until the ground is frozen solid. Then a water-tight shaft or tunnel is driven through the hard, frozen earth.

Refrigeration has conserved our foods and made easier their distribution from producer to consumer. It has made our public buildings more comfortable, and it has developed new industries and improved old ones. Yet, big as the refrigeration industry is, it utilizes the application of only a few simple physical laws.

Physical laws on which mechanical refrigeration is based

The basic principle upon which artificial cold is produced is well known. It is common knowledge that when ice melts the necessary heat is supplied by some adjacent body. Wider experience teaches that whenever any solid melts, a certain amount of heat must be supplied from the surroundings. A method for producing cold is, therefore, to use some solid that melts at a temperature lower than that of the space or material to be cooled. For ordinary temperatures the cheapest solid is natural ice. But other solids are sometimes used when a small quantity of heat is to be removed quickly, as, for example, in ice-cream freezers where some salt is mixed with water or ice. The salt absorbs heat on going into solution in addition to the heat absorbed by the melting ice.

Water vapor in condensing to the liquid state gives out a large amount of latent heat. And when water is changed back into water vapor it must have an equal amount of heat supplied to it. If, therefore, water can be made to boil, or vaporize, in any way it must take heat from its surroundings, even if these surroundings consist only of more water.

The evaporation of water is a cooling principle

Water placed in a porous jar and shielded from the heat rising from the ground will, if exposed to a dry atmosphere, undergo such a rapid evaporation from the jar's surface as to be cooled to a temperature palatable to the taste. The peoples of warm, dry countries have long used this method of cooling their drinking water.

Water evaporation may be accelerated by removing the air and vapor that press down

Bakelite Company

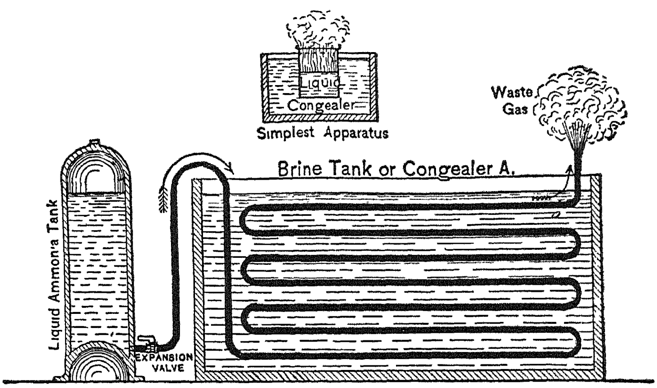
Insulated with glass fibers, this plastic thermal basket keeps foods and drinks either hot or cold.

upon it. Water placed under the bell of a vacuum pump will boil so rapidly that in a short time enough heat is removed to make the rest of the water freeze. This principle was used in small hand-operated freezing machines. The air pressure was removed with a small air pump and the water vapor was absorbed as soon as formed by hygroscopic (moisture-absorbing) sulfuric acid contained in a jar placed in the vacuum chamber. The process was continuous as long as the acid was strong enough to absorb the water vapor, and any receptacle placed in the water would be cooled the desired amount. The water-refrigerating machines using sulfuric acid as an absorbing agent were used considerably in the early days of artificial refrigeration, but they were soon outdistanced by the more convenient ammonia machines.

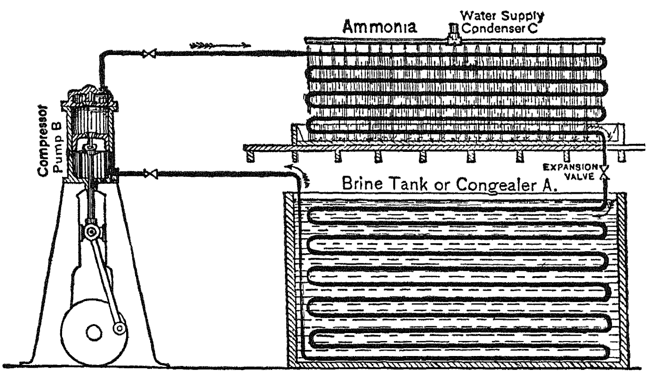
What is true of ice and water is also generally true of other solids and liquids. So, broadly speaking, we may say that whenever a solid changes to a liquid, or a liquid changes to a vapor, heat is taken (abstracted) from the surroundings, which are thus chilled, no matter whether they consist of different materials or of other

portions of the same material. As liquids are more easily handled than solids it follows that to produce mechanical refrigeration practically on a large scale it is only necessary to supply to the place to be chilled a continuous stream of liquid which may be evaporated by receiving heat from this space. As to which liquid shall be used, whether water, or ammonia, or carbon dioxide, or sulphurous anhydride, or liquid air, or ethylchloride, or laughing gas, or something else, is more a question of cost, and of danger and convenience in handling than of necessity. In practice we find the first four in use to a considerable extent, although ammonia is much more generally used than the others.

If an unlimited supply of some liquid that would boil in the atmosphere at low temperatures and give off a harmless gas were at hand, then the art of mechanical refrigeration would be exceedingly simple. For example, if liquid air could be manufactured at low cost, it could then be used as a refrigerant, as the vapor given off from it would simply be cold atmospheric air that could be used not only for further refrigeration as it warmed up, but would also serve to ventilate the refrigerators, warerooms, etc. Liquid air has certain advantages in that its presence would be beneficial and its pressure is sufficient to push back the atmosphere itself without the use of a compressor, but unfortunately it also has certain disadvantages. For one thing, it costs too much to manufacture; again, it boils at too low a temperature for ordinary refrigeration, which has to be somewhere in the neighborhood of 45°.



ELEMENTAL REFRIGERATING APPARATUS
Two parts Simplest form of refrigerating machine Refrigerant wasted.



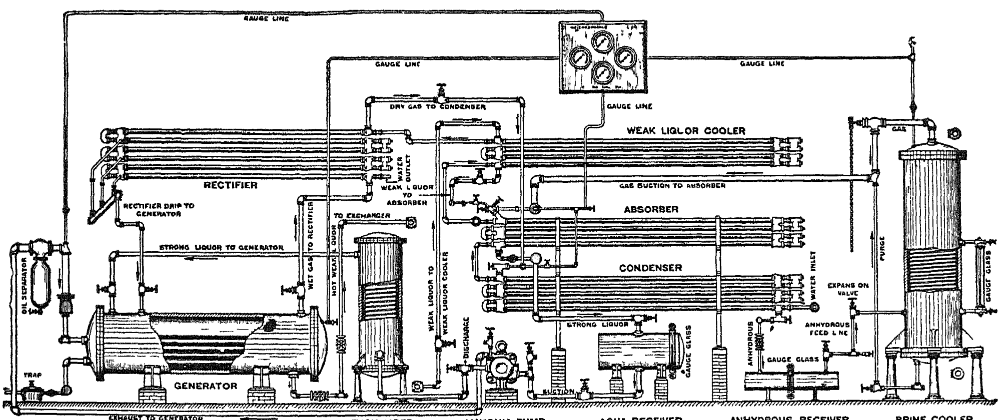
MECHANICAL-COMPRESSION REFRIGERATING APPARATUS
Three parts. Diagrams courtesy Frick Company Inc.

The sole complexity in the mechanical production of cold for commercial purposes lies in the difficulty encountered in first collecting the vapor as it escapes from the refrigerating coils and then changing it into a liquid for repeated use. The method ordinarily employed consists in drawing this vapor into a gas compressor or pump which through the application of power compresses the gas up to such a high pressure that its temperature is considerably greater than that of the atmosphere, and then in passing the hot vapor through a condenser whence it loses heat to the surrounding atmosphere and condenses into liquid form. This condensation can be accelerated by the use of cold water flowing over the coils. The liquid thus formed drains from the condenser into a receiving tank from which it is fed when needed back into the refrigerator coils ready to start a cycle once more. This method of restoring the cold vapor to liquid form involves complicated machinery and necessitates the presence of a trained engineer.

Another method of accomplishing this same result has been evolved which needs only a small pump in place of a large compressor and for domestic sizes can be operated intermittently without even a pump. In order to insure that the ammonia or other refrigerant shall continue to evaporate in the refrigerator coils it suffices to remove the vapor just as fast as it is formed. Water possesses the power of absorbing many times its volume of gaseous ammonia, so that a stream of water placed in the further end of the refrigerator coil acts exactly in the same manner as the suction stroke of the compressor, because the ammonia gas is immediately absorbed by the water and produces a vacuum into which more gas passes which in turn is absorbed. If, therefore, we wish to make the process continuous all we have to do is to supply a continuous stream of water to absorb the ammonia gas which is being produced.

Naturally ammonia and water are both too expensive to be thrown away, so that other pieces of apparatus are required to separate the ammonia from the water so that both may be used over again. This is readily accomplished by pumping the strong ammonia solution into a boiler where it is heated and a part of the ammonia is distilled off. This hot ammonia gas is then led into the condenser in just the same way as the hot ammonia gas delivered from the compressor is led into the condenser, while the water from which the ammonia has been distilled is led back to absorb some more ammonia. If water is used as a refrigerant, a stream of sulphuric acid could be used as the absorbent and by distillation the water could be driven out of the solution again and the sulphuric acid be ready for future use. This was the method involved in the early type of water refrigerating machines.

The close analogy existing between the pumping of water from an excavation and the removal of heat from a cold storage wareroom makes it clear why it will never be profitable to use liquid air as a refrigerating agent for ordinary work. To remove water from the excavation, a well is dug at the lowest point into which the water that seeps in through the ground may be drained and from which it is then removed by means of a pump to the upper level and thrown away. The bucket of the pump must first be lower than the water in the well, so that the water may flow into it. Then the bucket must be lifted by the application of power to such a point that when dumped the water flows down hill into the sewer. We could, if we desired, dig the well 100 feet deep and pump the water up from that level, by supplying sufficient additional power. But we would be throwing away the work required to raise the water from the bottom to the top of the 100-foot well without having gained any advantage. Obviously the deeper we make the well, the greater the useless expenditure of work required to remove the water.

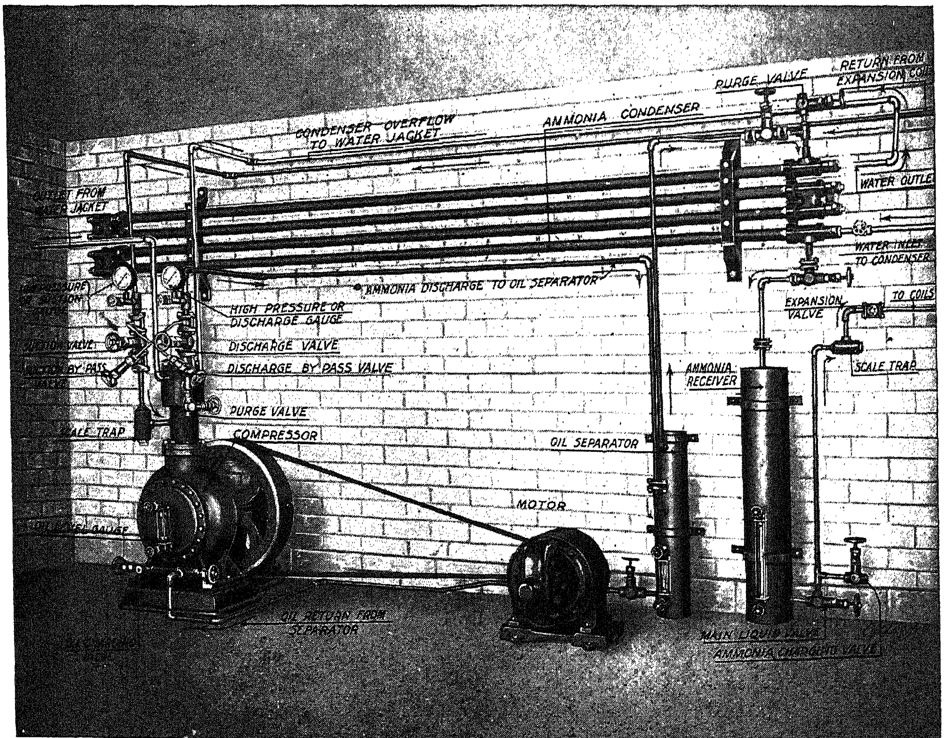


Courtesy Carbondale Machine Co

CARBONDALE TUBULAR TYPE REFRIGERATING MACHINE

The theoretical minimum of expenditure of work would be simply that required to raise the water from the bottom of the excavation to the top.

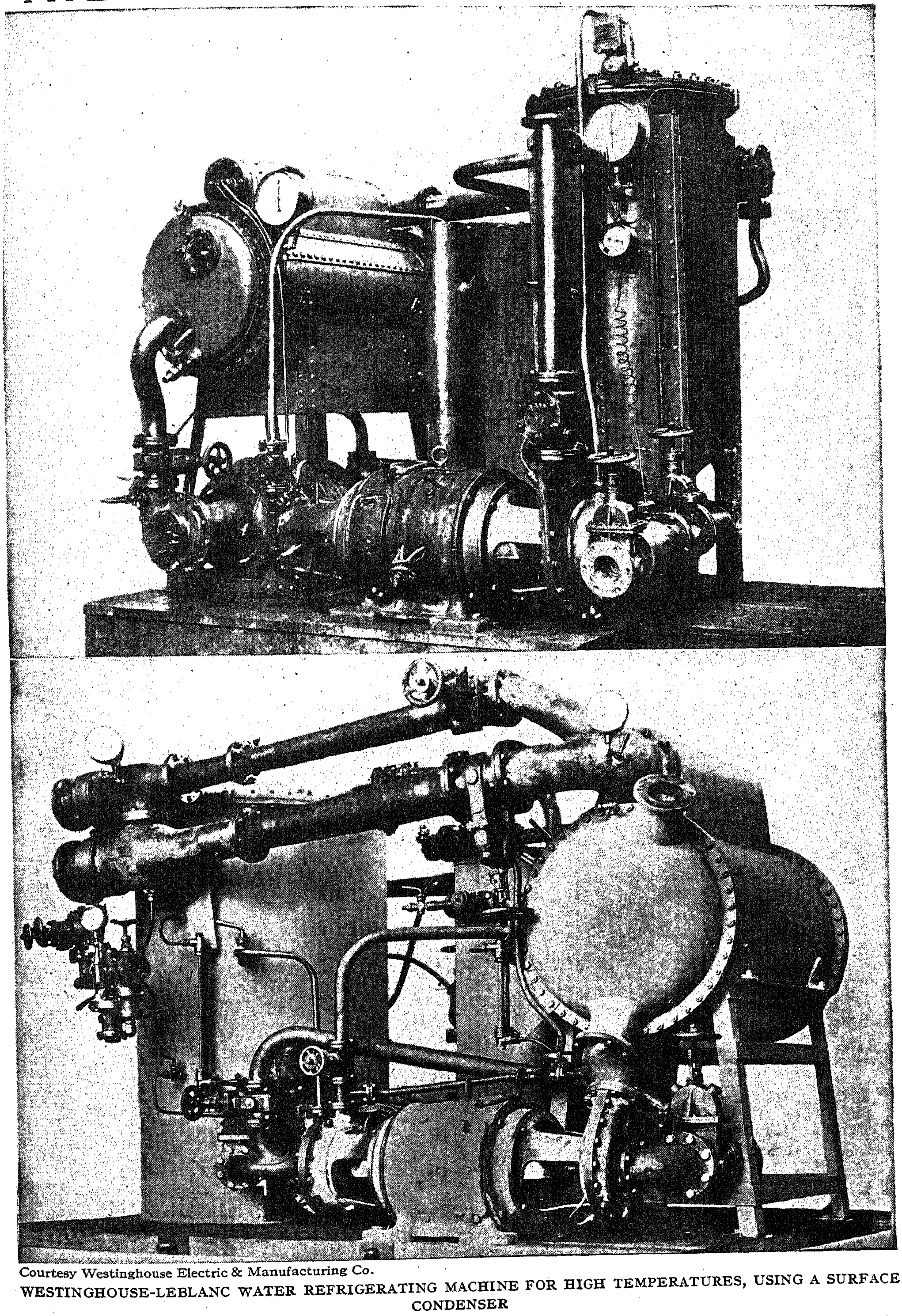
Similarly in a refrigerating plant, the refrigerant is located in a pipe in which by the removal of the vapor by means of a compressor the liquid is caused to vaporize at a temperature lower than that in the room, so that the refrigerant forms the point of lowest temperature in the room. The heat leaking in through the insulation then flows down hill from the room to the refrigerant. By the application of power the vapor is pumped up to a temperature so high that heat now flows out of it into the cooling water or into the atmosphere surrounding the condenser. If desired, the vapor compressor could be run at a higher speed, thereby reducing the vapor pressure on top of the vaporizing refrigerant so it would boil at a decreased temperature. This would mean that the vapor given off would be of a lower temperature and pressure and would occupy a larger volume, so that the work required to compress it up to the upper level would be correspondingly increased. If liquid air is used as the refrigerant, the temperature of boiling at atmospheric pressure is, roughly, $-313°$ F. To remove the vapor thus formed and compress it until it reached a temperature higher than that of the atmosphere, the amount of work required will be increased over that required for, say, ammonia, by an amount proportional to the additional range of temperature, through which the air has to be pumped. Liquid air is thus not an economical substance to use when only moderate degrees of refrigeration are required. It has, however, its proper sphere of use in physical investigations upon the properties of substances at very low temperatures and also as well in the production of oxygen and nitrogen from the atmosphere.



Courtesy The Brunswick-Kroeschell Co.

TYPICAL ARRANGEMENT OF MACHINE ROOM TWO-TON REFRIGERATING PLANT

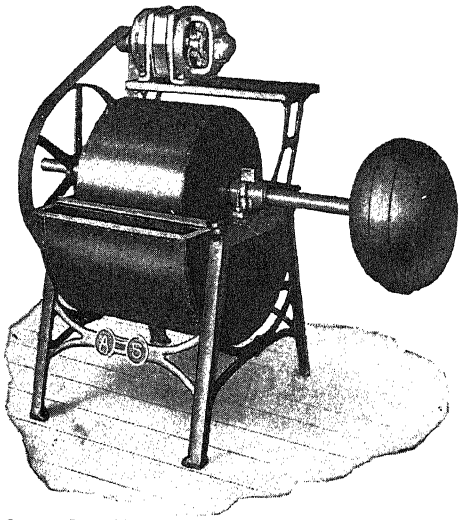
TYPE USED BY THE NAVIES OF THE WORLD



Courtesy Westinghouse Electric & Manufacturing Co.

WESTINGHOUSE-LEBLANC WATER REFRIGERATING MACHINE FOR HIGH TEMPERATURES, USING A SURFACE CONDENSER

If liquid ammonia is used as the refrigerant, satisfactory temperatures are easily attainable, as ammonia boils at $-27°$ F. in the atmosphere, and at 0° F. under a pressure of two atmospheres. Ammonia, however, in other respects is not as desirable as water or air, as it is not only expensive, but it is also a poison and cannot be permitted to escape into the atmosphere. This means that some sort of machinery must be installed to catch the ammonia vapor from the refrigerator coils and to change it back to a liquid for further use.



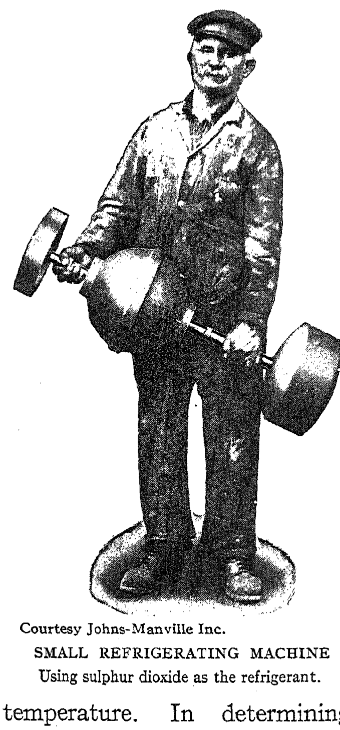
Courtesy Johns-Manville Inc.
ANDRIFFREN-SINGNON UNIT
Consisting of machine proper mounted on light steel condenser tank.

Water from many points of view forms an ideal refrigerant. It appears in liquid form in its natural state, it is always to be had, it is inexpensive, and it is harmless. But while liquid air, ammonia, sulphurous anhydride, carbon dioxide, etc., exert vapor pressures at temperatures below 32° F. sufficient to push back the atmosphere and thus continue to boil, water at 32° F. exerts a vapor pressure of about $\frac{1}{100}$ of that of the atmosphere and cannot boil. However, as we have seen, if the pressure is removed from the top of the water by means of a vacuum pump, air compressor, or other device, water will then boil at various low temperatures according to the pressure thus maintained.

The following table shows the pressure in pounds per square inch under which different liquids used in refrigerating machines will boil at various temperatures.

Refrigerant	0° F.	32° F.	83° F.	40° F.
Water		0.0887	0.1000	0.1217
Sulphurous anhydride	10.38	22.53	24.18	26.93
Ammonia	29.95	61.91	65.91	73.03
Carbon dioxide	314.	525.	550.	591.

It makes no difference, therefore, which refrigerant is used, some device is necessary to remove the vapor as fast as it forms; in the case of water to make boiling possible, in the other cases to prevent the escape of the refrigerant. The pressure of the escaping gas will, however, vary with the substance used as well as with its temperature. In determining the refrigerant to be used in any case and in providing a way to handle the vapor arising from the refrigerant, attention must also be given to the space occupied by this vapor so that the compressor will be large enough.



Courtesy Johns-Manville Inc.
SMALL REFRIGERATING MACHINE
Using sulphur dioxide as the refrigerant.

HARVESTING THE CROP OF NATURAL ICE

© Ewing Galloway, N. Y.

BY HAND

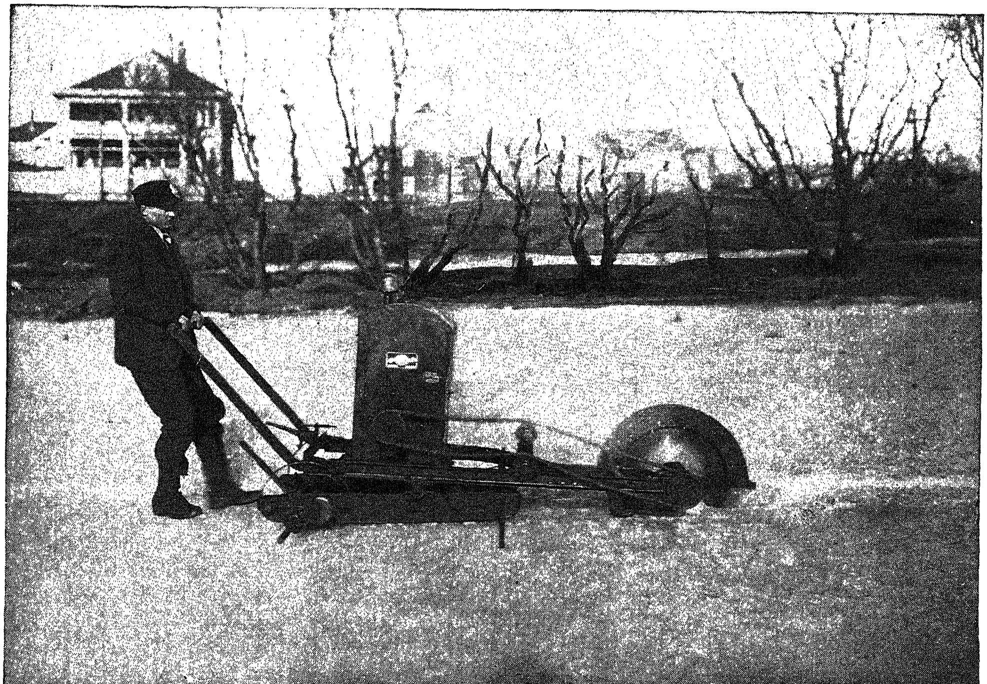
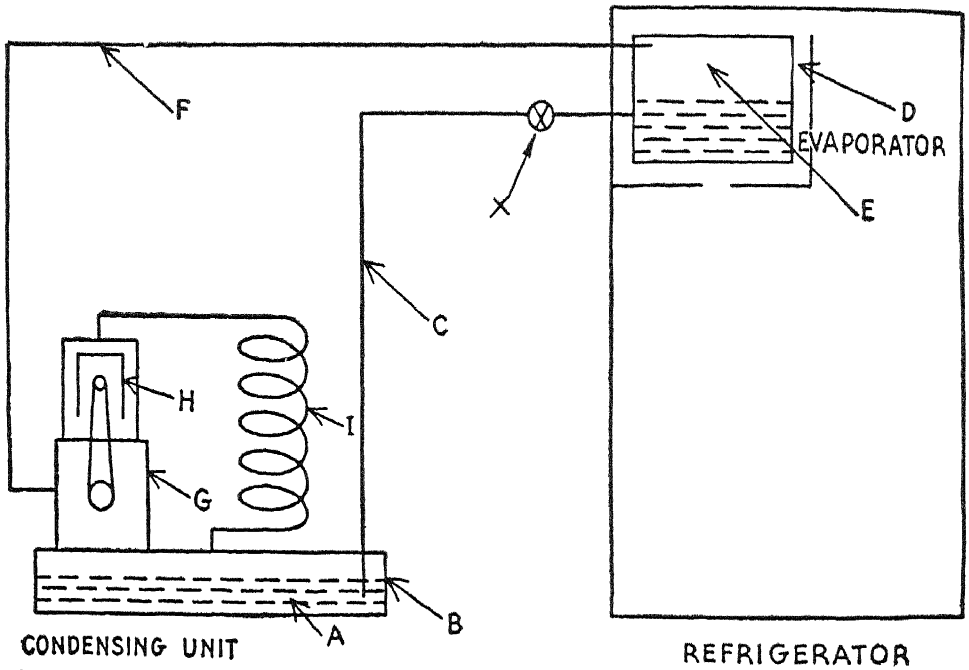


Photo Ewing Galloway, N. Y.

BY POWER MACHINE



Courtesy Frigidaire Corporation.

This diagram explains the principle of mechanical refrigeration as simply as possible. The refrigerating medium (A) in liquid form and under pressure, travels from the tank (B) through the pipe (C) and the control device (X) to the evaporator (D). Here the pressure is released and the liquid becomes a gas. As it expands it grows very cold and draws heat from the refrigerator. The gas (E) is drawn through the pipe (F) into the crankcase (G) of the compressor by the piston (H). This same piston compresses the gas into the condenser coil (I). As the gas is compressed its temperature rises and this heat is carried away by water or air passing over the coil. At the same time the gas turns into a liquid again and flows back into the tank (B). The cycle begins anew. This diagram shows direct refrigeration, generally used in household refrigerators.

An idea of the space occupied by different refrigerants is given in the following table, which shows the approximate volume in cubic feet of one pound of substance at different temperatures.

Refrigerant	0° F.	32° F.	35° F.	40° F.
Water (Steam)		3296.	2941.	2441.
Ammonia . .	8.19	4.631	4.364	3.959
Sulphur dioxide . .	7.54	3.65	3.43	3.10
Carbon dioxide . .	.284	.166	.160	.136

If each refrigerant absorbed the same quantity of heat during evaporation it would follow, for example, that the volume of water vapor would be about seven hundred times that of ammonia vapor for a given amount of refrigeration, but as water absorbs about twice as much heat as does ammonia, it follows that only about three hundred and fifty times as much volume of water vapor must be handled as ammonia vapor. This explains why water was not used for so many years because the capacity of the piston type of compressor had to be made so great as to be mechanically unfeasible. However, it has been found possible to handle large volumes of steam with rotary compressors and with steam ejector-compressors with comparative ease so that one development in mechanical refrigeration again embodies water as the refrigerating agent. Synthetic refrigerants such as Freon have also been evolved

WATER-BORN LAND ANIMALS

The Place of the Frog, the Toad, the Salamander and the Newt in the Scale of Life

STRANGE STORIES OF LOWLY NURSERIES

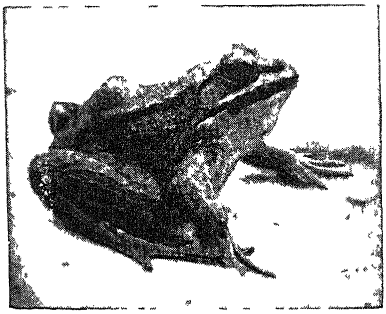
NEARLY two centuries ago a Swiss naturalist discovered in the Upper Miocene of his native land the skeleton of a four-limbed vertebrate. In his enthusiasm the naturalist bestowed upon it a Latin title signifying "the man who witnessed the Deluge". It became necessary for more scientific investigators to rename the skeleton, for the finder was slightly in error both as to classification and age. The remains were not those of an antediluvian man, but of an amphibian, a giant salamander, belonging to a class of animals whose antiquity, compared with that of man, is as the age of a patriarchal oak contrasted with that of a mushroom.

"A toad, eh?" said the ignorant countryman of the familiar story; "I'll larn ye to be a toad!" as he brought his spade down with a whack upon the unfortunate creature's head. The painful lesson, even had the pupil survived to profit by it, would have been superfluous, for toads were toads a very long time before certain other lower animals existed. The man did not know it, but the toad which he set out so emphatically to teach is one of the most remarkable links in the long chain of life stretching back to the world's dank, misty twilight. It is an animate chapter heading in the story of evolution.

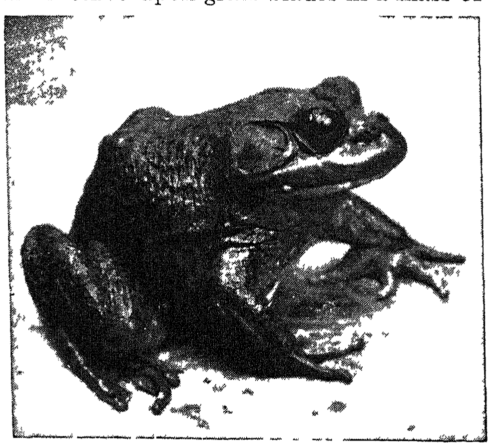
The dirtiest ditch in the country, teeming in the spring with its myriad writhing tadpoles, attracts the attention of the student, though the unobserving boy will pass it by, unless primordial savagery impels him to dash the life from a few of the humble creatures in the muddy channel. There, in that stagnant ditch, the story of animal creation is being retold. There is life, as once all pre-terrestrial life was, preparing for the first great adventure of existence, making ready to leave the world of waters, and to struggle, gasping, ashore, to possess the whole earth. Frogs and toads, newts and salamanders and their allies, which together constitute the great class of Amphibia, are among the most interesting relics of the past. They are the survivors of the forms which may have bridged the gulf between fishes and reptiles, whence came birds and mammals. This is not to say that the first terrestrial ancestor of man was toad or salamander, but it is related in the story of evolution that every other order of animals higher in the scale of life arose from the amphibian forms of which those to be dealt with in the present chapter constitute the survivors.

We group them in one class of two main orders — the ecaudata, or tailless, and the caudata, or the tailed; and for general purposes we term the whole Amphibia. The first order consists of the frogs and toads, the second of the salamanders and newts. By most of the laity these animals are all regarded as reptiles — cold-blooded, egg-laying animals. But they are not reptiles. The reptile resembles its parent at birth, in that it is not born in water, but is equipped with air-breathing lungs. The Amphibia hatch from eggs usually laid in the water, and after a time come to land to live.

The description is, however, inadequate Some of the Amphibia pass their lives in the water, while some are born on land That is, therefore, not a sufficiently comprehensive distinction. A further note of identification occurs in the fact that the larval amphibian is born with gills, not with lungs But even that does not hold good, for certain species do not make


THE COMMON GREEN FROG

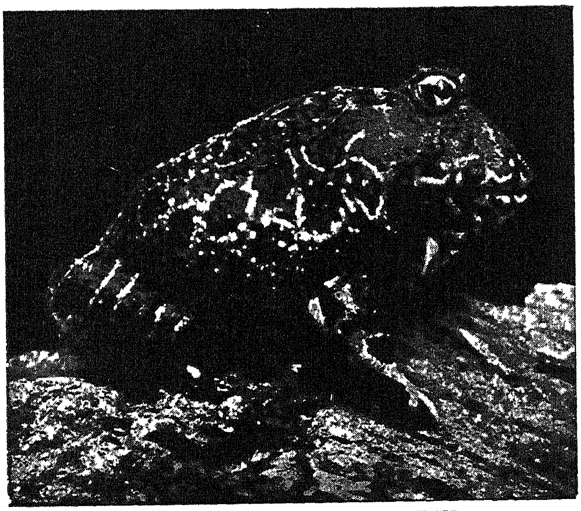
their appearance until gills have disappeared and lungs have fully developed. If we relied only upon nursery conditions, we should have to call the frog-hopper insect an amphibian, or else call one of the Amphibia by the name of this insect. Just as the eggs of the frog-hopper insect are hatched upon grass blades in a mass of


THE BULL-FROG

froth, so are the eggs of certain forms of these so-called water-born land animals hatched in frothy substances. Nor will it suffice to say that an amphibian must undergo a post-natal metamorphosis, for there are frogs and toads which leap from the egg-capsule as completely equipped as their parents, perfect in all but bulk. Against this we have others which attain to parenthood while in the larval condition

The many exceptions which present themselves to the rule propounded for the classification of Amphibia are, as a fact, not surprising, considering how very ancient is the class, how infinitely many the lines along which modification has been able to proceed The remnant remaining serve to remind us of the origin of the amazing family into which these primitive forms have branched. We cannot, of course, trace all the steps, for the connecting links are missing, but we are clear that the extinct labyrinthodonts, which were themselves not remotely removed from the fishes, connected the Amphibia generally with the anomodonts and beaked reptiles The Amphibia today have for the most part the same number of limbs as the higher mammals, and those limbs are similar in structure, possess the same number of segments and are supported by corresponding bones. But in other respects the anatomical structure of the amphibian is far more primitive than that of any other terrestrial vertebrate. How is it, then, it may be asked, that, with many points in common between the Amphibia and the higher animals, the Amphibia themselves have not advanced with the rest of terrestrial creation to become true reptiles, or birds, or mammals? The answer is that, when a class or order attains to a fair measure of generalization, it has a good chance of continuing in existence under conditions to the average of which it has adapted itself. It is those that become highly specialized which incur the greatest risk. Conditions specially favorable to a particular form of life, when they disappear, leave such form of life practically defenseless. The specialization already attained must be pushed forward at great speed to enable the animal to face other conditions, or death must be the penalty. Changes in physical and meteorological conditions have been responsible for the obliteration of many highly specialized types of ancient life. The more generalized animal, however, has been better fitted to meet the varying emergencies of its environment

A peasant household may produce a king or a line of kings, which line may die out and be forgotten, but the old peasant stock from which the kings were derived will continue in the village, healthy, humble, satisfied with its lot, little changed through generation after generation, though its collateral kin may tramp victoriously across a continent. Thus it may have been with the Amphibia. They may have given rise to many a line of kings, to all the kings, in fact, that the world has seen — reptile kings, bird kings, mammalian kings — and themselves have remained little changed, while around them their descendants have grown into forms and types such as all the books in the world would fail fully to describe. Many of these descendants were wiser than their parents. They learned to emancipate themselves from the neighborhood of water, to bring forth their young upon land, and so to claim the fairest places of the earth. The survivors of the ancestral stock have specialized only in minor particulars.



THE ORNAMENTED CYROTOPHYRUS

Structurally, the amphibian of today varies little from the earliest member of the class. Fins of the fish became limbs for progression on land, scales surrendered place to a smooth skin, and not one of the class remains which put on armor of plate or of bony scutes. The warty integument of the toad and the hairy covering of the West African frog (*Trichobatrachus robutus*) represent but insignificant modifications contrasted with the changes effected by earlier forms which passed on or passed out. Certain of the toads and salamanders have developed poison-glands, from which, in time of peril, a venomous secretion is produced, as from the fang of the snake.

That is the only defensive weapon to be found in the whole class, and is correlated with sluggishness of movement.

The frogs and toads have managed very well in life by depending upon agility — especially so in the case of the frog — and protective coloration to secure them against attack. And there is this striking fact to be noted: that as each member of the ecaudata has become more specialized as to reproductive process, the fewer have become its progeny. Those which possess no special means of safeguarding their young are fruitful beyond belief. Our common frogs lay literally thousands of eggs every spring, each of which, it is possible, may produce a tadpole. But no creature is more exposed to danger than the larva (or tadpole) of the frog. Carnivorous water-beetles, fish, birds, the cannibalistic propensities of tadpoles themselves, all help to reduce the number of the family. The progeny of a hundred frogs may *drown* if they cannot escape from the water in which they have passed their larval existence. We are not to imagine that frogs have consciously increased their output of eggs simply to make good the mortality among their offspring; the species has been kept in existence because the progeny which have survived have been those derived from a prolific strain. Those frogs which have developed the extraordinary nursery habits which we are to consider have necessarily lost this great power of increase; they could not rear vast numbers of young in such specialized conditions. It is to be noted, further, that those members of the class which have accustomed themselves to a circumscribed habitat are least numerous in species and individuals.

It will surprise the majority of people to know that the Amphibia number so many as a thousand species And it will surprise them still more to learn that the tailless forms, which in the perfect form are more free to wander and get the best out of life than are the salamanders, number nine-tenths of the whole. The class in its entirety is the least numerous in species of all the vertebrates, but the persistence, even in such numbers, of so ancient a type is a fact at which to marvel.

The life-story of the common frog, toad and newt is familiar to most of us The female frog deposits a vast mass of eggs in water, where, having been fertilized by

THE TREE-FROG

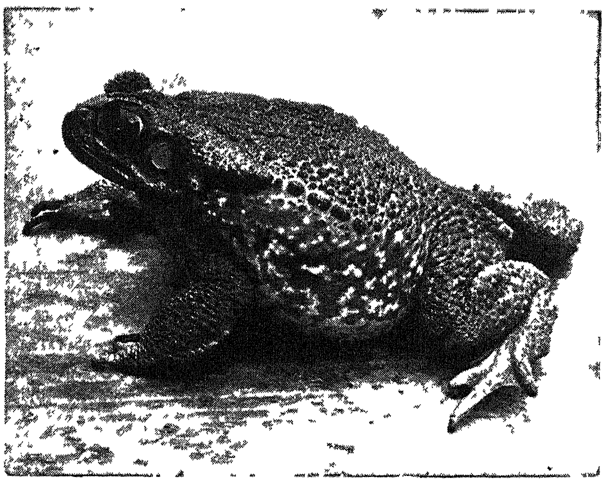
the male, they remain untended, and hatch in from ten days to a fortnight. Frost does not kill the life within the egg, but arrests its development, while moderate heat hastens it. When the larva leaves the egg it is furnished with external gills, which are presently absorbed, and are succeeded by internal gills Subsisting upon vegetable or flesh food, which it assimilates by means of suction and by means of a pair of horny serrated jaws, the little creature is in appearance a free-swimming fish. Soon, however, the hind legs bud out and push their way through the skin. Considerably later the horny jaws are cast, and the true frog's head appears, the forelegs are thrust out, the tail is gradually absorbed, and the little fish that was must come out of the water or die So out it comes, and becomes a carnivorous land-animal ready to feed upon slugs, worms and insects which it seizes with its jaws or by means of the strangely fashioned adhesive tongue that lies with the free tip pointing towards the throat

The skin of the frog is smooth and moist; that of the toad is warty and better adapted to the retention of moisture The frog, as the prime leaper of the order, is longer in the hind legs than is the toad. The breeding habits of both are very similar, except that the eggs of the toad are laid in strings, not in a mass, as in the case of the frogs

So much for the common toad and frog, in which the process of development from the egg to the perfect form is in the manner described There are twenty genera of these frogs, but we need not note them all. Many of them are widely distributed, being absent only from South America, Papua and New Zealand. In habits they vary considerably, some being more or less arboreal, while others are proficient and persistent burrowers. Among the typical frogs is *Rana esculenta*, the edible species, inhabiting Europe, large part of Asia and Northwest Africa. Giants there are in these days even among the frogs. The redoubtable bull-frog of eastern North America measures from 7 to 7½ inches in length, exclusive, of course, of the legs, but, this is not the largest of the frogs, that place of honor being occupied by *Rana goliath*, a denizen of the Cameroons, where it attains a length of 10 inches, exceeding by 1½ inches the dimensions of Guppy's frog from the Solomon Islands, whose length matches that of two huge toads — one from Malay and the other from South America.

Our departure from the typical frogs brings us to several remarkable groups. The first consists of the flying frogs, as they are called, which, by means of their amply webbed feet, "parachute" from considerable heights in the trees upon which they search for their insect prey.

Then we have the forest frogs, largely arboreal in habit, and separated by a considerable distance genealogically from the true tree-frogs. Here are three groups all more or less arboreal, and distinguished by very remarkable breeding habits. The flying frogs deposit their spawn on the broad leaves of bananas or other trees Certain of the Dendrobatidæ, or forest frogs, place their eggs in damp spots on land, others in the water; and when the eggs are hatched the tadpoles are carried upon the back of one of the parents, the larva adhering by means of its sucker mouth.



THE SOUTH AMERICAN GIANT TOAD

In another group containing the species the *Rhacophorus schlegii*, the female makes a hole in swampy ground, and secretes a fluid, which is beaten by the action of her feet into bubbles. In this her eggs are laid. When the tadpoles hatch, the bubbles subside and return to liquid form, in which the larvæ complete their metamorphosis, then escape to water. Among the tree-frogs proper are nest-builders, frogs which join two leaves together to form a cup, and in this cup secrete a frothy mixture, in which the eggs are hatched, and the young remain until they develop internal gills, at which stage they drop from the nest into the underlying water, and there complete their course of development. Here, then, we have the nursery scheme of the frog-hopper insect.

THE MOORISH TOAD

But not all these nest-builders construct their frothy cradles in trees. One of the tree-frogs excavates a hollow basin in the soil, and within it makes its nest of bubbles. That done, it constructs a tunnel outward from the nest to the adjacent river; and it is by way of such tunnel that the larvæ, as they leave the egg, will instinctively wriggle to undergo their metamorphosis in the water. Some of the species hatched by this process are intolerant of water in their early stages The tadpoles of a Brazilian tree-frog, *Hyla nebulosa*, for example, if taken from their frothy cradle, very soon die if placed in water. Clear water, of course is meant, for it should be noted here that no amphibian known to man can long endure even the slightest degree of salt in the water it frequents.

The nest of froth is notable enough, but among the nest-builders is an engineer of skill more challenging even than that of the tree-frog already mentioned which makes a basin upon a riverside. There is one genus of tree-frogs, *Hyla faber*, a Brazilian representative, which emulates the beaver. This interesting creature con-

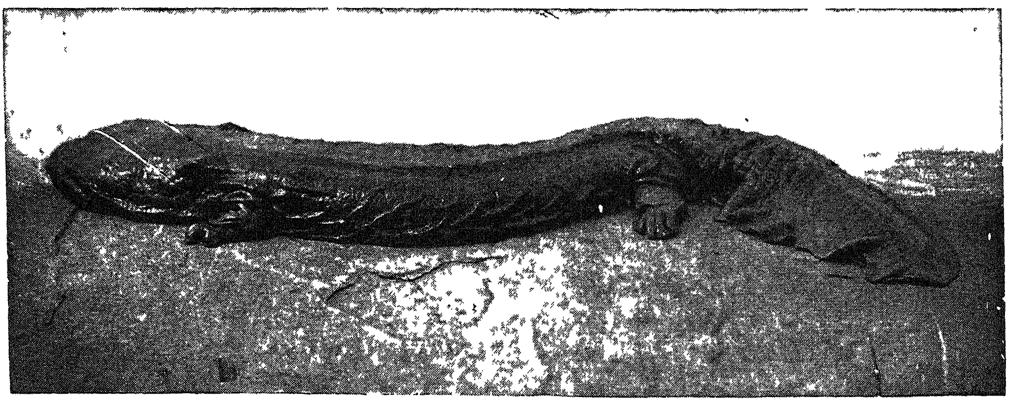
structs a circular dam in the water. Burrowing in the mud at the bottom, it carries up, with hands and breast, load after load of soil. With this soil it constructs a perfect rampart, circular in outline, with the parapet raised above the level of the water. The base of the defense is made firm and smooth by the creature's body; the walls are rendered hard and water-tight by the action of the hands of the frog, which it uses as skilfully as any aboriginal mason. The result is the formation of a sheltered pool, completely defended against invasion by carnivorous insects and other aquatic enemies of youthful frogs.

So far we have reviewed the habits of frogs which seek external nurseries for their progeny. But there are many genera in which the parent's body is itself the cradle. The best known of this type is the midwife frog, *Alytes obstetricans*. Here the male receives the eggs as they are laid by the female, which deposits them in long strings. These he winds about his hind legs, and faithfully carries them until the period of incubation is over. As a rule, he retires to some moist retreat near a pool or stream, where he is invisible by day. At night, however, he comes out and seeks his food, apparently quite unhampered, occasionally taking to the water, for the purpose, it is believed, of insuring the requisite degree of moisture for the eggs. The latter are three weeks in hatching, and the larvæ, carried to the water by their solicitous sire just before they break from the shell, swim away at once to take care of themselves.

The female of a Brazilian tree-frog, *Hyla goeldii*, carries her eggs upon her back. The eggs rest tightly glued to the skin of the back, the edge of which is slightly raised to preserve the embryos in place. When the capsules burst, young frogs emerge — not tadpoles but frogs with mouth and limbs complete, but retaining the tail which distinguishes the last days of the larval stage of the common frog.

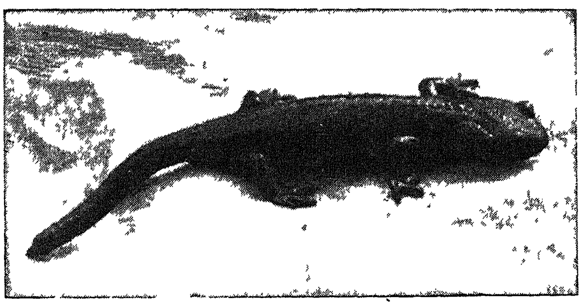
In cases such as this, where precocious development occurs, some very special provision is always to be noted for the breathing of the young amphibian. To take the place of the gills some unique adaptation is usually present, either in the form of a tail richly charged with blood-vessels, or some particular excess of skin, similarly equipped, by means of which oxygen can be absorbed directly into the blood.

The Surinam toad has advanced beyond the methods of the two genera of frogs last mentioned. In this case the female receives the eggs upon her back, where they are placed in position by the hands of the male. Here, however, the eggs are not allowed to remain exposed. The skin of the female grows round and over them, so that each egg is inclosed in a cell of the mother's external integument. As many as 100 eggs are carried in this manner by the female, and from each cell a perfect little frog ultimately emerges. Thus the complete metamorphosis is undergone without risk of exposure to animal enemies in water or nest.



THE MENOPOMAS, THE GIANT SALAMANDER OF JAPAN

More specialized still is the nursing plan of certain South American tree-frogs known as the Nototrema, or pouched frogs. In this instance the female, at the approach of the breeding season develops upon her back what may be described as a marsupial pouch. In this the male, by means of his hind legs, places her eggs, where the young are hatched in safety. There are several species of these frogs, and it is significant that where the larvæ escape into the water in tadpole stage the eggs are numerous, as if to cover all risks; but where the young are produced as frogs, then the eggs are few, sometimes only three or four, never, so far as is known, more than sixteen or eighteen. It is not only in any one species or genus that the larvæ undergo full development before passing out into the world. There is a mountain-haunting frog of New Guinea (*Phrynixalus biroi*) which deposits its eggs in an elongated, transparent membrane, and leaves all to hatch out as they will. And here the little ones do not appear until they have passed the tadpole stage. Still the list of strange nurseries is not exhausted. One of the most remarkable of all remains, that of Darwin's frog (*Rhinoderma darwinii*), the male of which has so modified its vocal sacs as to convert them into receptacles for the eggs of his mate. The pouch, which becomes an extensive chamber on the under surface of the body, is entered by two channels, situated on the floor of the mouth, and into this — the most curious of all nurseries in terrestrial animal life — the eggs are received, there to remain until the young, numbering a dozen or more, have not merely quitted the egg, but passed through the larval stage.


THE SPOTTED SALAMANDER

Modifications and adaptations are to be traced in many directions in addition to the reproductive habits of the tailless amphibia. We have noted the flying frogs and the tree-frogs, the latter furnished with sucker discs to their toes resembling those of certain lizards. It is not difficult to imagine how this feature developed, for, as everyone who has kept and bred frogs is aware, the young batrachian, even of the common American species, has for some days after quitting the larval stage the power of climbing up a perpendicular surface, simply by the sucker-like action of its clammy little feet. This power, however, is not retained by the adult frog.

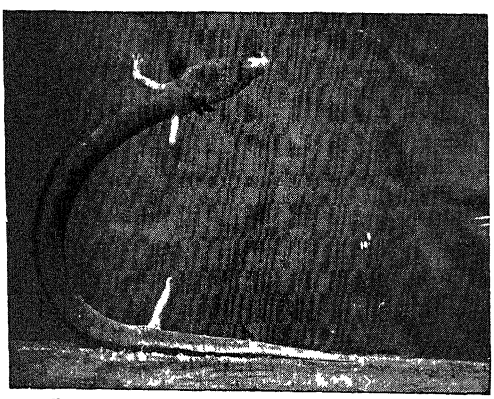
Other strange examples of amphibian life are the narrow-mouthed frogs, the short-headed frogs, with enormous balloon-like bodies, the fantastic sharp-nosed frog of the Solomon Islands, the horned frogs of tropical America, which, with a length of eight inches or more, and great bulk, are the most ferocious of the order, preying upon lesser frogs and small mammals, and even daring, in self-defense, to attack human beings. The piping frogs, too, are famous not less for their music than for their nests, carved out of the mud in such a position that the larvæ when they emerge will be received by a timely flood and gently carried into the river. These frogs belong to a sub-order remarkable for the entire absence of a tongue, a peculiarity shared by the Surinam toad and the spur-toed frogs or toads. Of these the smooth spur-toed frog is exclusively aquatic, pursuing even its prey under water and effecting their capture by means of the forefeet.

The second order of the Amphibia, the salamanders and newts, have not been so closely studied as the frogs and toads. Newts are generally regarded as poisonous, and salamanders were in early times credited with occult powers of withstanding and of rather enjoying the flames of the fiercest fire. The whole order is exclusively nocturnal, and in place of actual knowledge a body of myth and legend has grown up around it, which will take ages to dispel.

So limited has been our knowledge of some genera that it was not until recently that we knew that the formidable autodax (so called in reference to the teeth with which it defends itself against attack) lays its eggs in trees The discovery was accidentally made in the grounds of the University ot California, where men,

THE AXOLOTL

cleaning and dressing the trunks of oaks, found strings of eggs in holes thirty feet up the stems of the trees. At first regarded as a freak on the part of a single salamander, the position of the eggs was found to be normal The autodax does actually dwell amid trees, and there lays its eggs, and broods them with great devotion.



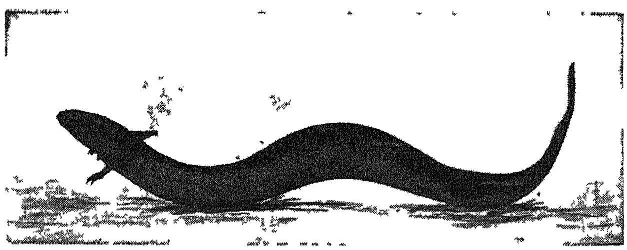
THE OLM FROM THE CAVES OF CARNIOLA

This example of solicitude is not isolated, nor is the autodax the only member of the order to frequent land for the rearing of its young. The Alpine salamander, for instance, which ranges between heights of from 3000 to 10,000 feet up the Alps, not merely avoids the water for her nursery, but produces her young alive, and that by the most curious process yet observed. Of fifty eggs which the oviducts may contain, only two are fertile The tadpoles, when they emerge from the egg, are not at once extruded from the parent body, but are nourished upon the substance of the remaining eggs, so that the favored pair undergo their metamorphosis amid an abundant food supply, and emerge in the likeness of the parent form, from which they differ only in point of size The European spotted salamander may be said to be both oviparous and viviparous, since both eggs and tadpoles may be produced at one and the same season.

Included in the best-known groups of the salamander tribe are the spotted, the spectacled, the Spanish, the Caucasian, the several genera of cave-dwelling salamanders and the famous axolotls Among the cave-dwellers are some which pass their lives in subterranean waters. The complete life-histories of these have not yet been worked out. Some years ago we knew nothing of *Typhlomolge rathbuni*, when from an artesian well at San Marcos, Texas, 188 feet deep, a dozen specimens of a strange, semi-transparent, slender-limbed salamander were cast up, furnished with external gills, and having the eyes functionless. At first, it was not known whether this was the larval form or the adult. The discovery of an adult form identified the salamander from the Texan well as in the larval stage.

The tiger salamander (*Amblystoma tigrinum*), which is not uncommon to many parts of the United States, is, for ordinary purposes of identification, not greatly different from other salamanders, and its young undergo the usual larval metamorphosis resembling that of our common little newt. But the case is different in certain lakes by which the city of Mexico is surrounded One of these lakes is brackish, and contains no form of amphibian life. In the freshwater lakes, however, axolotls abound. But here these creatures never advance beyond the larval stage. That is to say, they never become air-breathers in the ordinary sense, but retain their gills throughout life. They were found to resemble the amblystoma in all but the vital point as to breathing.

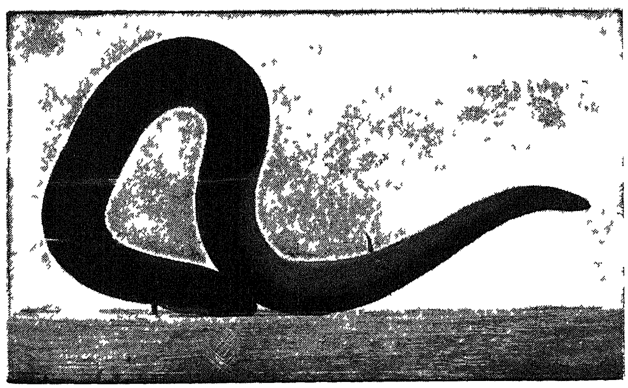
The amblystoma passes through the ordinary larval stage and acquires lungs, and becomes an air-breather; the Mexican axolotl remains a water-breather. Naturally, then, the two salamanders were referred to different genera It was accidentally discovered at the Paris Jardin des Plantes that axolotl and amblystoma are one and the same — that the former is simply the larval stage of the second. When water in their tank was diminished, the axolotls rapidly lost their gills, developed lungs and became air-breathers in the ordinary sense They had become amblystoma! Yet in the Mexican lakes in which they flourish, for some reason which naturalists have not yet been able to fathom, they never pass beyond the larval condition. They issue as larvæ from the eggs, they develop as larvæ, and they breed as larvæ, yet every one of them is capable, we are to believe, of turning into the adult form of the amblystoma. And possibly each would do so were the supply of oxygen in the water insufficient, so compelling them to draw upon the atmospheric air for supplies.



SIREN OR MUD-EEL OF THE SOUTHERN UNITED STATES

The salamander from the Texan well has a famous relative in Europe in the olm. This is an eyeless gilled salamander, dwelling in the subterranean waters of caverns in the Alps of Carniola, Dalmatia and Carinthia We do not know upon what it feeds in its natural state, but in captivity it takes, when so inclined, small worms, crustacea, and minute forms of life found on aquatic plants. It is very sensitive to light, and will shift into a dark corner of its tank should a sun-ray illuminate the water It has been found to breed in captivity, sometimes producing eggs, sometimes live young, but all attempts to cause it to substitute gills for lungs have so far failed.

Another curious form of salamander is the mud-eel of the southeastern United States, which is compared to a snake with external gills and a pair of short forelegs. Then there is the siren, or mud-eel, which has both gills and lungs. This salamander has been proved, again by accident, to be really independent of the former organs, a fish in an aquarium having devoured the gills of one which afterwards lived unhampered, depending upon its lungs for oxygen supply. Then there are the cæcilians, blind, limbless amphibia, which, when they quit the larval stage in the egg-mass deposited in mud or other damp situation by the parent, escape to the water to complete the metamorphosis, returning afterwards to land for the rest of their lives, to burrow in mud and soft, damp soil, and lead a worm-like existence, in all but the matter of diet, which is carnivorous.

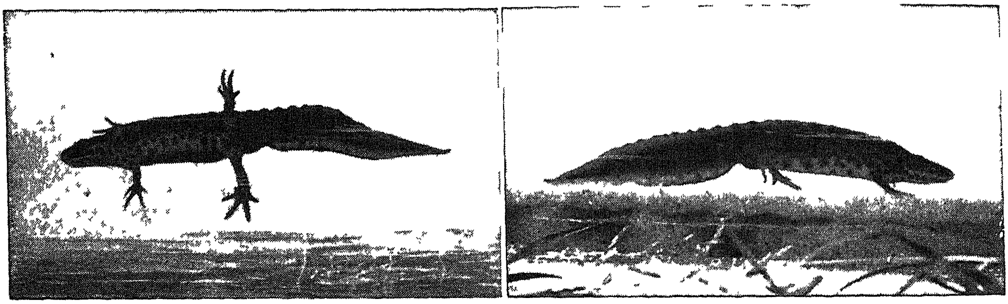


THE AMPHIUMA OF NORTHERN AMERICA

Our review closes by a return to the commoner forms of the order, the fish-like salamanders, so called from the fact that these, which constitute the family Amphiumidæ, are entirely aquatic It was one of these, a giant salamander, whose remains startled the Swiss naturalist into the belief that he had found a man who had witnessed the Deluge. The first living representative of the giant salamander was discovered nearly a century ago

in Japan, and one was first brought to Europe in 1829. Its supply of fresh-water fish failing on the voyage, the male ate its female companion, but dwelt apparently without remorse in an aquarium at Amsterdam for fifty-two years thereafter.

Giant salamanders live in the mountain streams of Japan and China, and are never known to quit the water. The eggs are carefully tended by the male, which coils itself round the mass — numbering some 500 eggs — until, at the end of about ten weeks, the young emerge. They differ little from the tadpoles of salamanders and newts, possessing in the early stages of their existence gills that are afterwards lost.

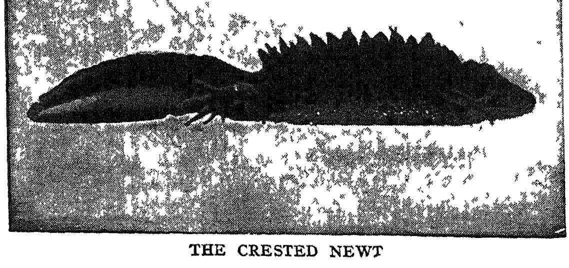


THE SMOOTH NEWT SWIMMING AND AT THE BOTTOM OF A POND

Little need be said of the European newts. The fertilized eggs are attached by the female to leaves of aquatic plants, and the young, upon emerging, bear gills resembling those of toad and frog. But whereas in the latter the hind legs always first appear, with the newt it is the fore pair which first develop. In the adult stage the newt takes to the land and seeks damp, secluded situations, returning to the pool only at breeding-time. They cast their skins occasionally, more frequently when young, and eat them. They are very elusive little creatures.

The common salamander, or spotted newt of the eastern United States (*Diemyctylus viridescens*) has a still more interesting life history. It hatches from the egg in the water, lives as a purely aquatic creature for several months, and then changing to a beautiful red above, with deeper reddish spots, and lemon yellow beneath, with black spots, he crawls out of the water, breathes by means of lungs and lives a wholly terrestrial existence for about two and a half or three years. Then he takes to the water again for the rest of his life In this second aquatic stage he is olive green above with red spots, and lemon yellow beneath, with black spots. When full grown it is about 4 inches long. It lives in ditches and quiet waters where it feeds voraciously on all sorts of aquatic animals.

There is yet much to learn as to the life-history of many of the Amphibia. They are, despite their lowly organization, among the most interesting relics of the past still preserved to us, and by their history, they seem to maintain intact the bridge from which life passed out of the waters into the great world beyond. They have still many secrets to declare to the student who will diligently seek and observe.



THE CRESTED NEWT

Bell Aircraft Corp.

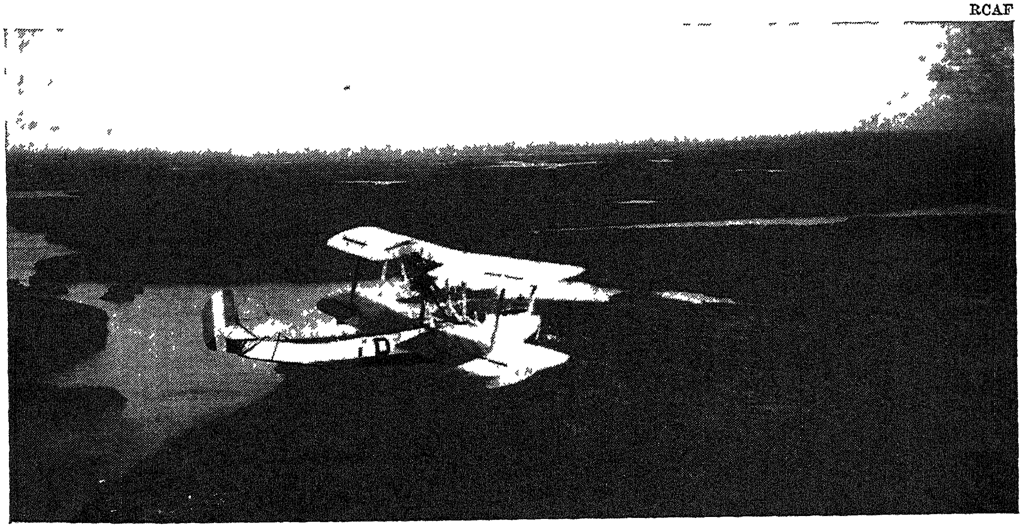
Taking a news photograph from a helicopter, which hovers almost motionless above the scene of action.

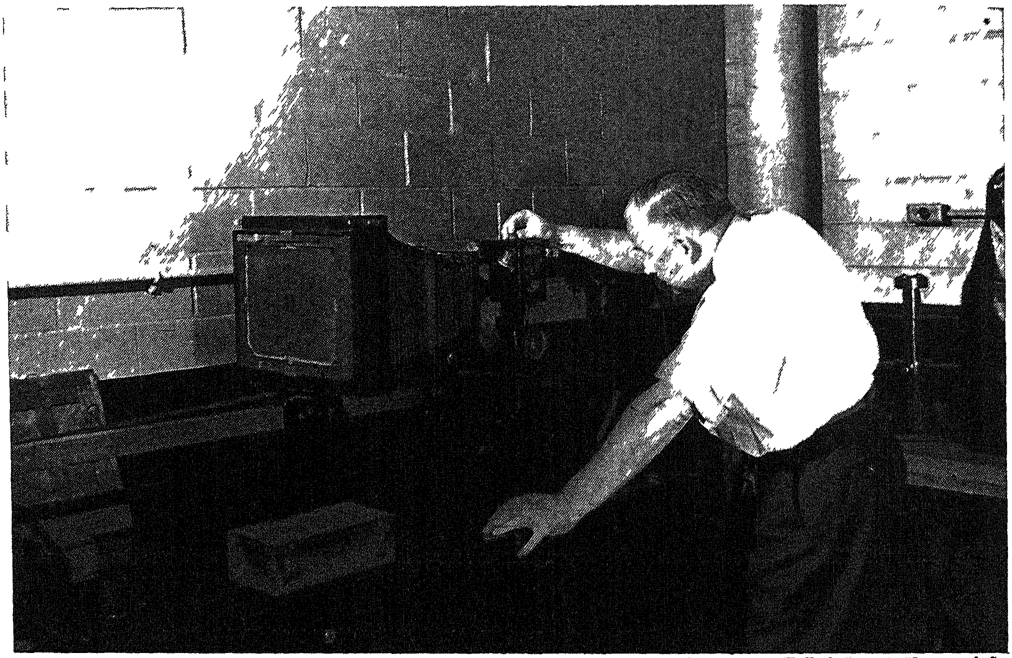
PHOTOGRAPHY AT WORK

The camera is a never failing source of entertainment for those who desire to keep a pictorial record of their own doings and those of their relatives and friends. But it is much more than a satisfying hobby for amateurs; it is an indispensable tool in the work of the newsman, the surveyor, the astronomer, the metallurgist, the botanist and a host of others. It provides them with a wide variety of data; it brings before them the infinitely large, the infinitely small and all that lies between. In these pages we show some of the ways in which the camera has served.

The Royal Canadian Air Force has worked since 1921 at the monumental task of photographing Canada from the air. Shown below is an RCAF Vedette, used for this type of work in the 1920's and 1930's.

RCAF

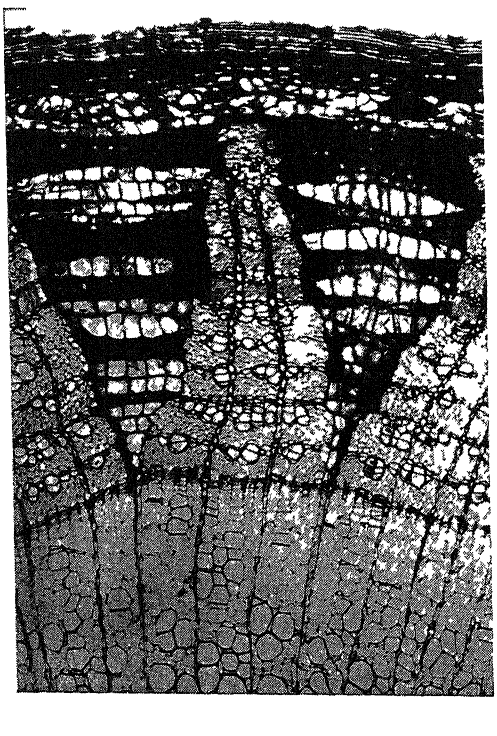


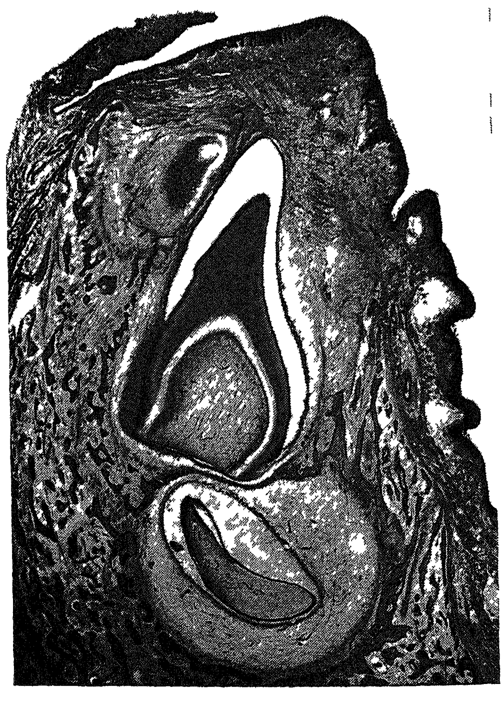


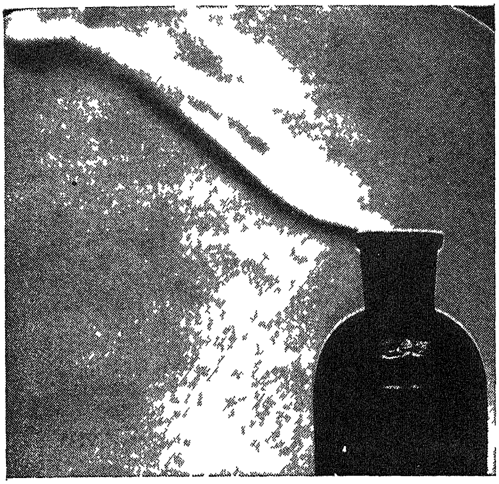
Upper photo E I du Pont de Nemours & Co

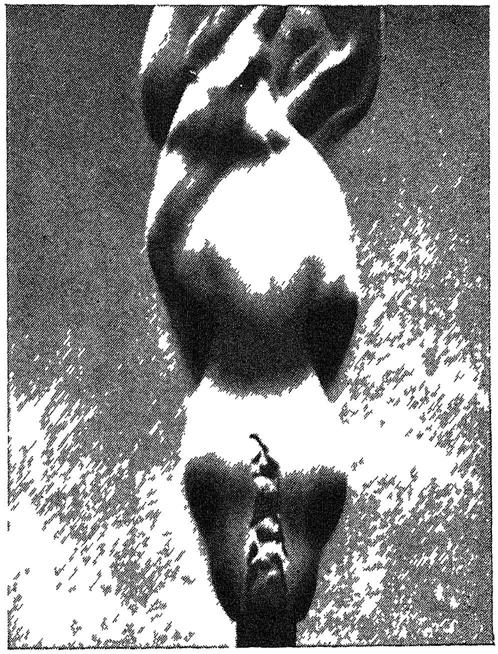
Among the most valuable contributions of photography to science are photomicrographs, which are enlarged photographs of microscopic objects taken by attaching a camera to a microscope Above we see a metallurgist making a photomicrograph of a test sample of ore Below are two photomicrographs Left cross section of the stem of a bass wood tree Right gum of a newborn baby The upper tooth shown here under the surface of the gum is the temporary tooth, the lower one is the permanent tooth Of course the upper tooth, closer to the surface of the gum, will erupt first

Lower photos Julius Weber



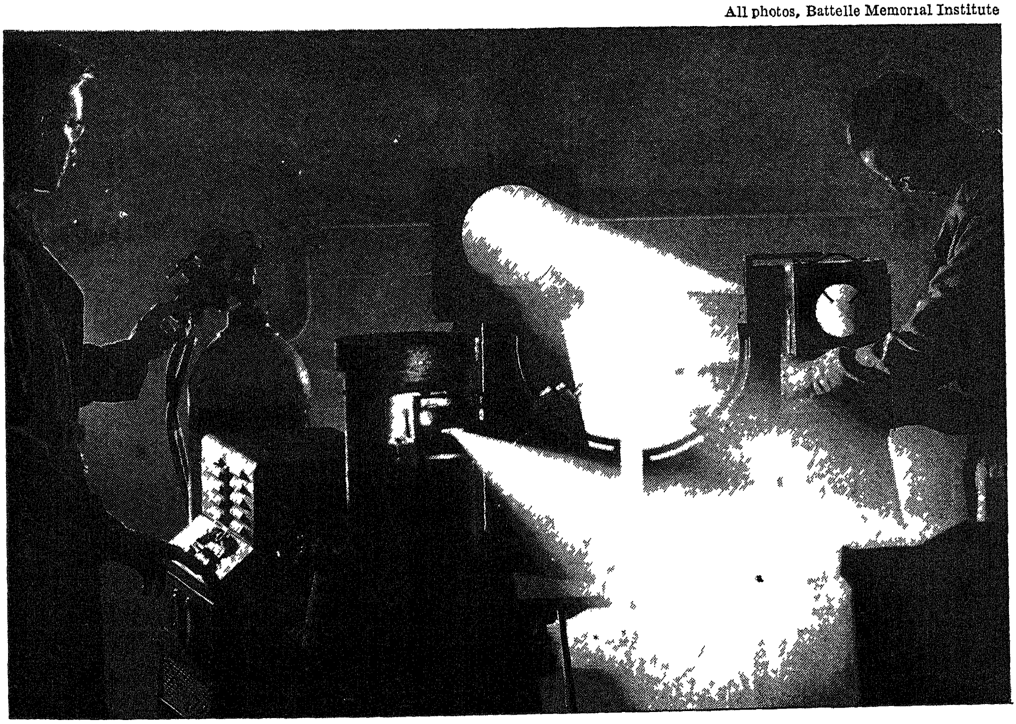


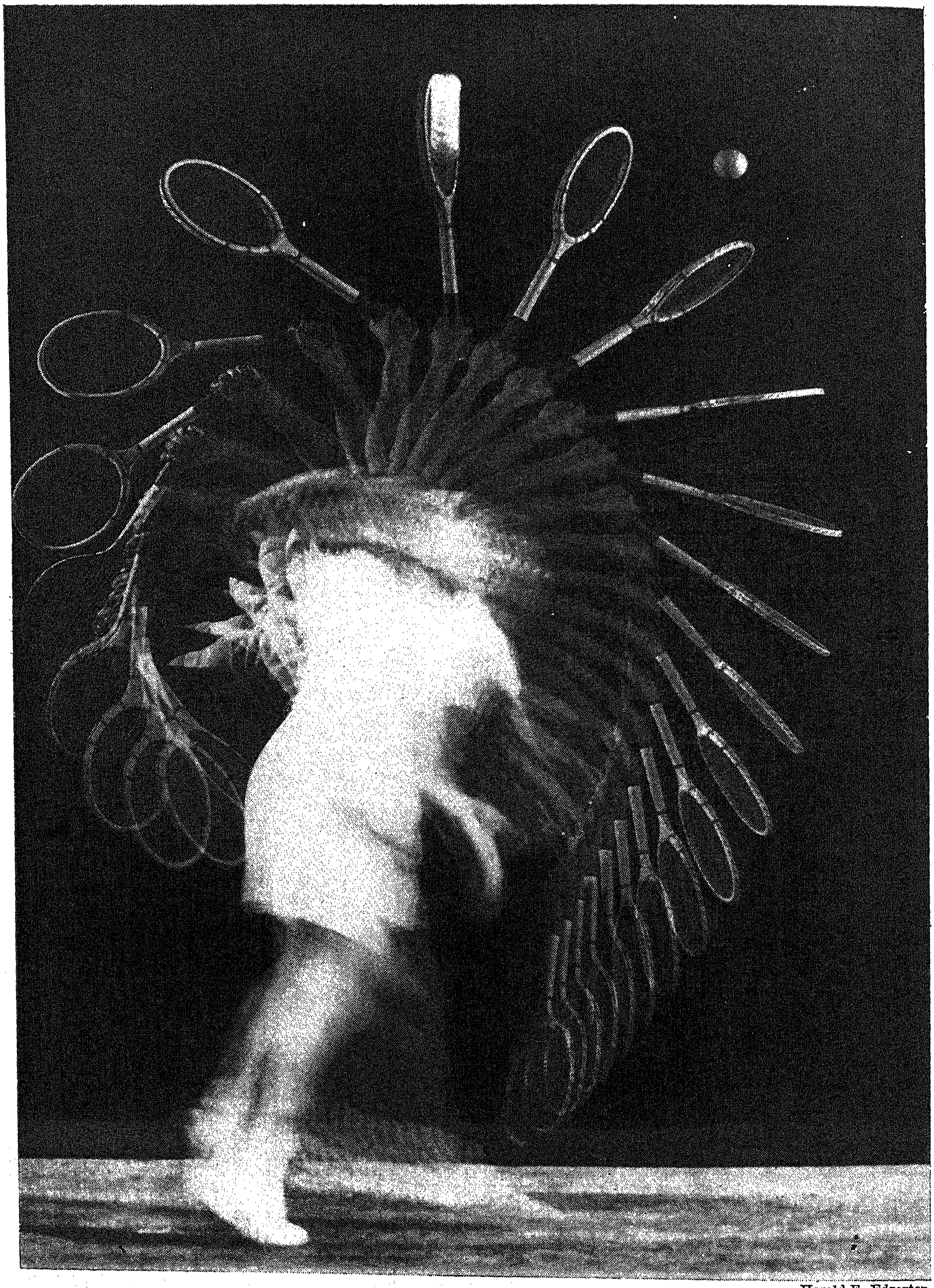




Those who make a special study of gases are able to see them by means of an ingenious device called the schlieren apparatus (*Schlieren* is a German word meaning "striations" or "streaks") The schlieren apparatus was first used by August Toepler, a German scientist, in 1864, its basic principle has remained unchanged In this apparatus a curved mirror focuses a narrow beam of light so that all the rays are parallel As the rays pass through the gas that is being studied, they are bent as a result of differences in density, temperature and pressure in the gas The bent rays are then focused on a viewing screen Cameras can be used with a schlieren apparatus to make photographs of gases Below we see the equipment used in making such pictures Above are shown two schlieren photographs At the left, heavy acetone vapor is flowing out of a bottle At the right, air currents are rising above a gas flame, the core of unburned gas shows in the center of the picture

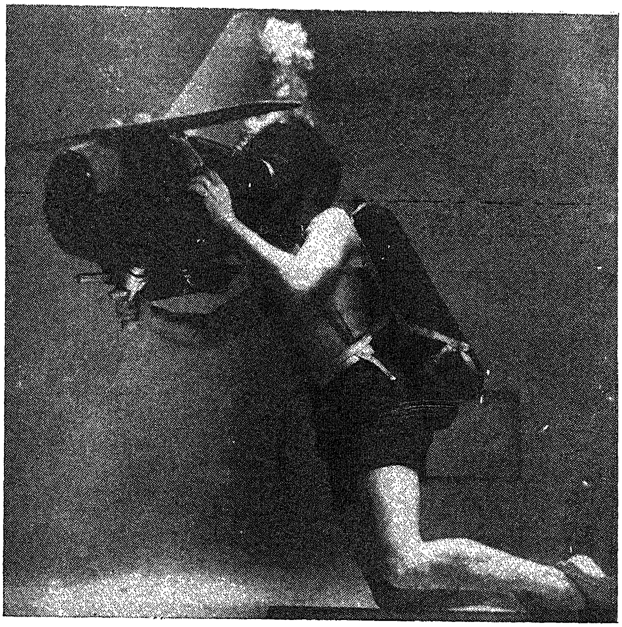
All photos, Battelle Memorial Institute





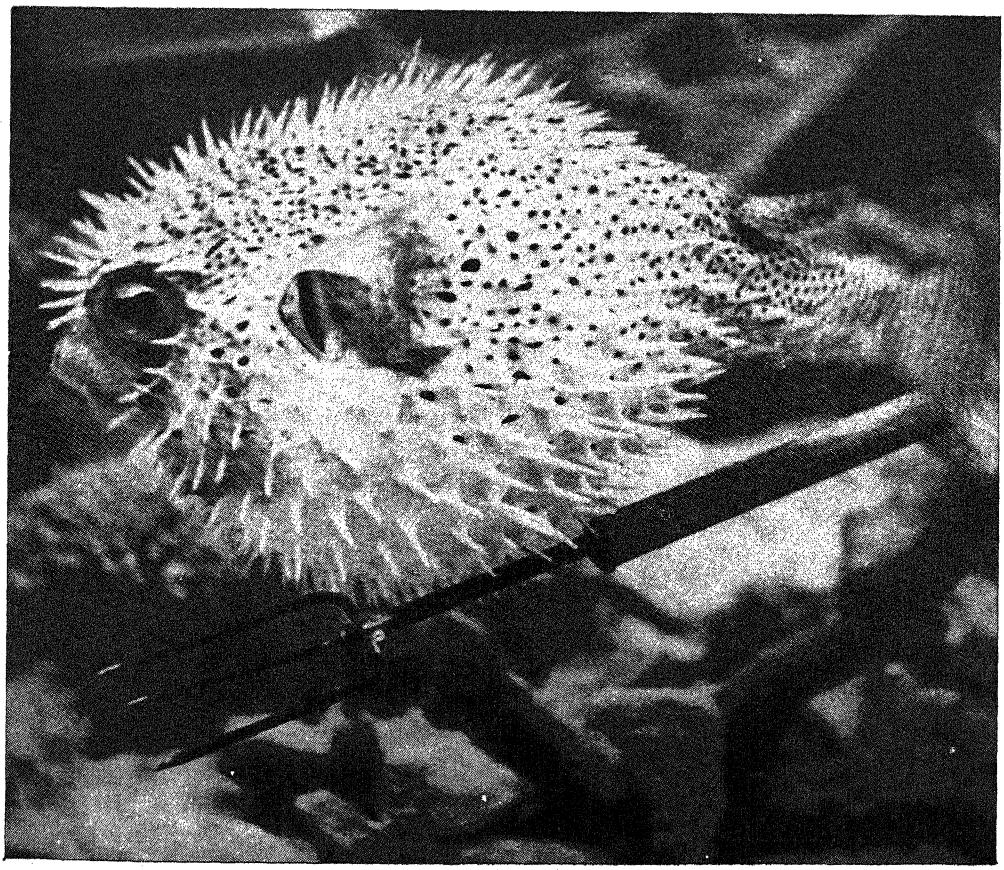
Harold E. Edgerton

The light for this striking high-speed photograph of a tennis player in action was provided by a stroboscope, a device that illuminates any given object with a rapid succession of bright flashes.



The camera has been used for many years to record the wonders of underseas plant and animal life. At the right is seen a particularly effective type of underwater camera, known as the underwater blimp from its superficial resemblance to the aircraft of that name. This camera is provided with wings and a rudder, which help to stabilize it. Here the photographer-diver is adjusting the lens diaphragm. The lower photograph, taken with an underwater blimp at a depth of thirty feet, shows the fish that is called the puffer because it can inflate its body.

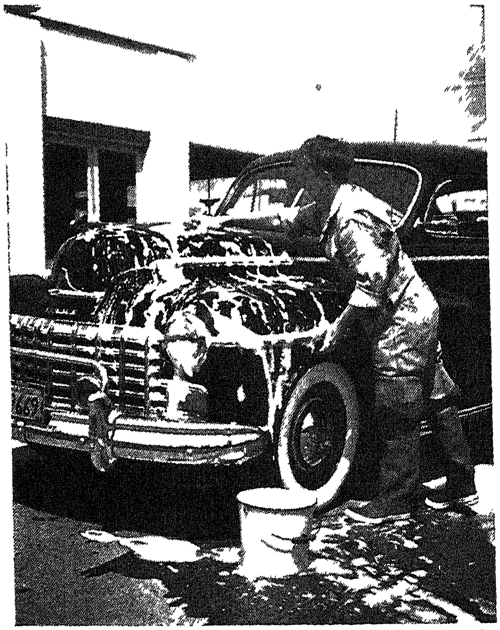
Both photos, USN



HOW SYNTHETIC DETERGENTS SERVE

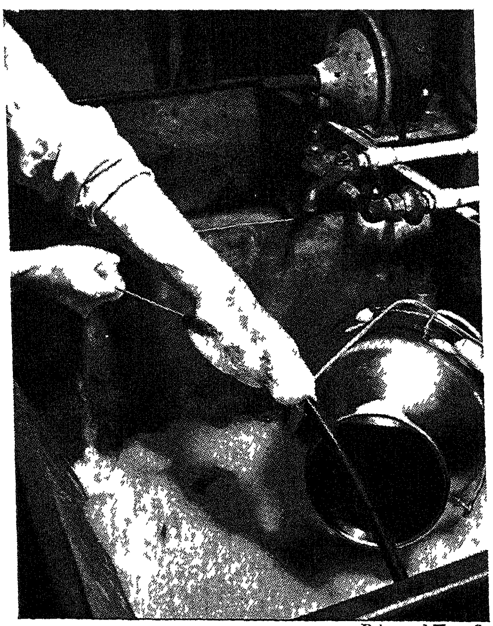
Tide

A woolen blanket can be effectively cleaned in a washing machine by adding a detergent to the water.



Rohm and Haas Co

A grease-removing solution made up of a detergent and water leaves fewer streaks on car enamel



Rohm and Haas Co.

Detergents combined with bactericides are used in cleaning milk containers and other dairy equipment.

U S Dept of Defense

Hosing off with water the detergents used on a plane that had been subjected to radioactivity.

THE QUEST FOR CLEANLINESS

Soaps and Synthetic Detergents at Work

A DETERGENT is a cleaner—the word comes from the Latin and means to "wipe off" or to "de-dirt." The most common of all detergents is soap, which has been in use for more than two thousand years.

Since no soap of any kind is found in nature, man must somehow have stumbled upon the process of making it many centuries ago. Perhaps some primitive hunter was sitting by his fire, roasting the meat of an animal he had just killed. Perhaps by accident some of the hot animal fat dropped into the ashes of the fire. If the hunter later picked up some of the mixture of fat and ashes, he may have discovered that it had the apparently magic power of cleaning the dirt from his grubby hands. Our own ancestors, much later, learned to make soap by mixing lye and hot grease or fat. The lye they obtained by allowing hot water to drip through wood ashes—a process known as leaching. The making of soap was an essential and time-consuming household task—almost as important as the weaving of cloth and the cooking of food. Of all the man-made synthetic chemicals, soap was probably made at the earliest date and has had the widest use.

Until recently, however, scientists did not understand clearly how soap goes about its important work of helping to keep the world clean. With a better understanding of the cleaning process, they are now able to make new synthetic detergents—soapless soaps—that have proved to be much more efficient and more versatile than soap ever could be.

The same cleaning principle is involved in soaps and in synthetic detergents, even though soaps are made mainly from fats and vegetable oils while synthetic detergents are made from the by-products of petroleum refining. The molecules of which soaps and other detergents are composed behave in a very special way.

One part of each molecule is attracted to water; the other part is repelled by water, but is attracted to oil or grease. When a detergent is used, for example, in laundering dirty clothes, the "oil-loving" part of the molecule will be attracted to the greasy dirt on the clothes, while the other part will be attracted to the wash water. In the course of the tug of war that ensues, the particles of dirt are broken up and fall into the wash water. The detergent then coats these bits with a skin of detergent to keep them from joining other bits of loosened dirt in the wash water and clumping together.

A good detergent must also be a wetting agent. Clusters of its molecules crowd the surface of the water, reducing surface tension and making it easier for the water molecules to penetrate the fibers of the substance that is to be cleansed. (Special wetting agents produce the wetter water used in fighting fires; the water forces its way into the interior of wooden beams and even into bales of cotton.)

Useful friend to man that it has proved to be over the centuries, soap has many serious disadvantages. For one thing, it is almost impossible to obtain suds in cold, salt or acid water, or in water that is very hard. (Water is hard to the degree that it has absorbed certain minerals—magnesium and calcium—from the earth or the air, or from both.) When used with hard water, soap combines with the mineral salts, forming a deposit or scum that is very difficult to rinse out entirely. This scum is noticeable in the washing of clothes and in the ring that sometimes forms around a bathtub. The soap that goes into the formation of this scum or curd is wasted, of course. Fortunately, synthetic detergents can now

be used for many purposes that soap could not serve.

Today the word "detergent" is a familiar household word. From the shelves of grocery stores, the housewife can make her choice of hundreds of synthetic detergents. In making her choice, she should realize that different kinds are used for different kinds of work. If she is wise, she will read the labels and choose the detergent especially suited for the kind of work she wants it to do. (She might be surprised to discover that some very special types of detergents are used for purposes far removed from cleaning, as we shall see.)

Each synthetic detergent is designed to do one kind of work supremely well, although most of them will perform several kinds of work with great efficiency. Practically all of them, unlike soap, lather well in hard water and some can even be used in salt water. Because the organic (carbon) compounds of which they are made do not react with the minerals in water as soap does, they leave no deposit or curd, even when used in the hardest water. From this point of view they are less wasteful to use.

The same substances that make it possible for detergents to break up the dirt and soil in clothes are also used in the preparation of hand lotions and medicines—but, of course, not as cleaners in this case. Most hand lotions contain talcum powder to make the lotion smooth. Detergents break up the particles of talcum into tinier bits, coating them in the same way they coat the particles of dirt in washing, and not allowing them to form into masses or clumps.

Special detergents that produce a great deal of foam and froth are especially recommended for shampoos. Others, which produce a small quantity of suds, are suitable for use in dish-washing machines where masses of suds would take up too much room and actually make the dish-washing process less efficient. As many a housewife has discovered, dishes, glassware and utensils washed with proper detergents do not need to be wiped. They dry by themselves with a sparkling cleanness. The new cleaning aids are used to perform such heavy work as keeping railroad locomotives and city streets clean. They remove the oil film that often causes city streets to become slippery and dangerous. Upholstery, fine silks—almost anything that needs to be cleaned—profit by the use of detergents.

We have seen, in the case of hand lotions and medicines, that detergents are sometimes used as dispersants, to keep tiny particles within a liquid dispersed, or separate, from one another. Certain detergents also act as emulsifiers—in solutions where oil and some other liquid with which oil does not easily mix need to be brought together. Some detergents are used in motor oil to prevent sludge from settling out. Others can be used, since they have no taste, to take the place of egg white in cake-making, and in cleaning vegetables, such as broccoli.

Among the most useful of the detergents are the quats—quaternary ammonium compounds—which not only clean but also destroy germs. The quats are now widely used in hospitals for sterilizing the hands of surgeons about to perform surgical operations and also for sterilizing the skin of patients before an incision is made. Before quats were known, the surgeon spent long and tedious minutes washing his hands over and over again to remove any germs. The quats now do the job in a very short time.

Since they almost completely destroy the bacteria that are found in milk, the quats are finding new and wider uses in the dairy industry. Because they leave no taste, they are ideal for sterilizing milk cans and bottles as well as other dairy and restaurant equipment.

Drinking water can be made much safer by the use of the quats. In very weak solutions they do not hurt human beings but they do destroy any harmful bacteria found in drinking water. It has been pointed out that in the case of germ warfare, the quats could protect water supply against deadly pollution.

The first of the new synthetic detergents were discovered in Germany, and quickly found favor in the eyes of textile manufacturers because of their efficiency in cleaning wool. The first household detergent was offered to the public in 1936 and was soon followed by many others.

RECORDING THE FLEETING DAYS

The Development of Calendars That Fit the Seasons

by

ELISABETH ACHELIS

IF the average man were asked to name the things most essential to him in the daily round of his activities, the chances are that he would not include the calendar among them. Yet in every civilized age, ancient and modern, the calendar has been indispensable. It enabled the men of early times to plan ahead for the sowing, growing and harvesting of crops and for various other activities as well. In our own far more complex civilization, the calendar is even more important. Our complicated industrial structure, with its system of contracts, drafts, checks and promissory notes, is dependent upon it; so is the political structure; so is the intricate tapestry of history; so is the individual citizen in his private life.

The calendar of today is the product of a great many centuries of patient study and of constant trial and error. When man first looked to heavenly bodies for a yardstick for the measurement of time, he observed that the sun seemed to make a constantly repeated journey in the heavens, always returning to the same place after many days. (Actually, of course, it is the earth that makes a yearly revolution around the sun.) He observed, too, that the moon went through a cycle in the course of which it waned until it could no longer be seen and then waxed until it became once more a bright disc in the sky.

Most of the earliest calendars were based on moon cycles, which were made to fit as best they could within the larger framework of the sun cycle. The year, in these calendars, generally consisted of twelve moon cycles, or months. Since twelve moon cycles are not quite equal to a solar year, an extra month—called an intercalary or inserted month—was added from time to time. A number of ancient peoples, including the Babylonians, Hebrews, Greeks and Romans, adopted this method of computation.

The Egyptian sun calendar

The Egyptians were the first to base their calendar on the sun cycle and to make the month a purely arbitrary unit, not corresponding to the actual lunar cycle. They worked out a year of 360 days, with 12 months of 30 days each. Since, according to their reckoning, it took 365 days for the sun to complete its journey in the heavens, they added 5 days to the end of the 360-day year. These added days were considered as feast days and the Egyptian priests were entrusted with the important task of arranging for them.

The Egyptians observed that the inundation of their land by the Nile River lasted four months, that the planting and cultivating of the crops took up four more months and that it took another four months to complete the harvesting. They remarked, too, that the bright star Sirius began to rise in the sky together with the sun at just about the time that the Nile began to overflow. Therefore the Egyptians divided the year into three seasonal periods of four months each; and they began their calendar with the day on which Sirius began to rise in the east with the sun. (This corresponds to July 19 in our calendar.)

This Egyptian 365-day calendar was adopted in the year 4236 B.C., according to the reckoning of the great American archaeologist James Henry Breasted (1865-1935). According to Breasted, it was the "earliest known and practically convenient calendar of 365 days"; as for the year 4236 B.C., it marked "not only the earliest fixed date in history but also the earliest date in

the intellectual history of mankind." This Egyptian calendar was the ancestor of the Gregorian calendar of today.

In the course of the centuries that followed, it was discovered that the year really consisted of 365 days and about a quarter of a day. This additional quarter of a day was causing a gradual shift of the seasons as recorded in the calendar. It meant that the first month of the Egyptian calendar came to coincide not with the flooding of the Nile but with the harvest period, and, later, with the period of the planting of the crops. In 238 B.C. the pharaoh Ptolemy III, also known to history as Euergetes I, tried to correct this obvious error in calculation by adding another day to the calendar every four years. It was to be a religious holiday and was to be known as the Festival of the Good-Doing Gods. Unfortunately, this edict, which was known as the Decree of Canopus, was not generally adopted. The priests, whose duty it was to adjust the feast days, were unwilling to accept the extra day since it was not in keeping with the traditions built up under the old arrangement; and the people were just as reluctant to make the change. As a result the Egyptian calendar continued to be defective as a measure of the seasons.

Days of the Month	Martius Maius Quintilis October	Januarius Sextilis December	Aprilis Junius September November	Februarius
1	Calendae	Calendae	Calendae	Calendae
2	6	4	4	4
3	5	3	3	3
4	4	Pr d Nonas	Pr d Nonas	Pr d Nonas
5	3	Nonae	Nonae	Nonae
6	Prid Nonas	8	8	8
7	Nonae	7	7	7
8	8	6	6	6
9	7	5	5	5
10	6	4	4	4
11	5	3	3	3
12	4	Pr d Idus	Pr d Idus	Pr d Idus
13	3	Idus	Idus	Idus
14	Pr d Idus	19	18	16
15	Idus	18	17	15
16	17	17	16	14
17	16	16	15	13
18	15	15	14	12
19	14	14	13	11
20	13	13	12	10
21	12	12	11	9
22	11	11	10	8
23	10	10	9	7
24	9	9	8	6
25	8	8	7	[6]
26	7	7	6	5
27	6	6	5	4
28	5	5	4	3
29	4	4	3	Pr d Cal Mart
30	3	3	Prid Calen	
31	Prid Calen	Prid Calen		
DAYS	31	31	30	28-29

The Julian calendar. The Latin names for the months are given; they are easily recognizable, since all but two of them have been retained, with certain changes, in our calendar.

The Mayan calendar

Another seasonal sun calendar that was used in antiquity was that of the Mayas of Mexico. It probably goes back to the year 580 B.C. According to a renowned American archaeologist, Sylvanus Griswold Morley, it was the first seasonal and agricultural calendar in America.

The Mayan calendar was similar in some respects to that of the Egyptians. It consisted of 360 days, with a period of 5 days, necessary to complete the year, added as a short month. As we saw, the Egyptians dedicated the 5 extra days in the year to the gods, but the Mayas considered them as evil days upon which no work could be done, no journey undertaken and no marriage performed. As in Egypt, arrangements for the extra days were left to the priesthood.

The Mayan calendar was arranged differently from that of the Egyptians. The year had 18 months of 20 days. The 20 days within each month were divided into four 5-day series, corresponding to our weeks; each day had its own name. The 20

days of the month began with a cipher; hence the days were numbered from 0 to 19 inclusive, not from 1 to 20 inclusive, as we would count the days in our months.

Dovetailed with the Mayan sun calendar was another imposed by the priests, who used a time system of their own for ceremonial rites and purposes. This was the permutation system, or tzolkin. In this system there were 20 months of 13 days each existing within the framework of the 18-month 20-day year. It was as if we were to have a 260-day year start on January 1. The 260th day would correspond to September 17; the first day of the new 260-day year would then correspond to September 18.

The calendar of the Aztecs was based upon that of the Mayas. The Aztecs realized that a year consisted of 365 days plus a quarter of a day, approximately. Each year they stored away the additional quarter-day for future reference. The slack was finally taken up when a cycle of 52 years had been reached. It is thought that the Aztecs came to realize that an intercalation of 13 days was too long and a 12-day intercalation too short. Hence a 12½-day insertion completed the 52-year cycle. In a period of 104 years (twice 52) 25 such days were added. By this method the Aztecs adjusted their calendar to the seasons.

The Julian calendar

The Egyptian sun calendar was most carefully guarded by rulers and priests and consequently remained unknown to the outside world for more than thirty centuries. Only during Julius Caesar's stay in Egypt did he learn of this calendar, which was immensely superior in every respect to the one used in Rome.

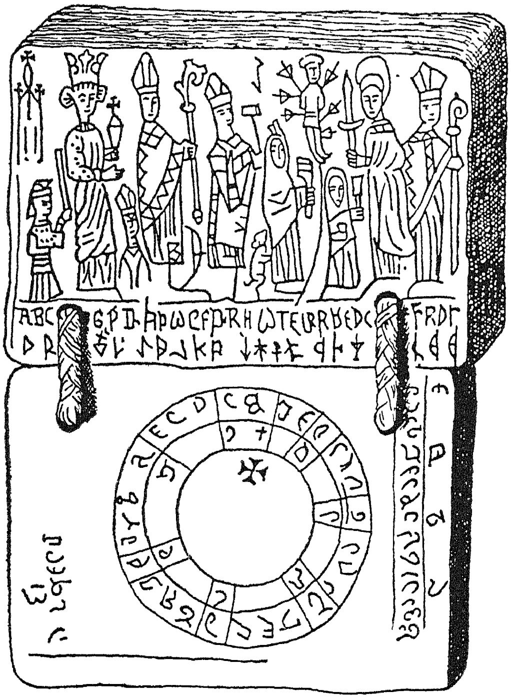
As we have seen, the ancient Romans had a moon calendar; it was complicated and most confusing. There were 12 months; a thirteenth month, called Mercedonius, was occasionally inserted in a haphazard way. The 12 months of the Roman year consisted of 7 months of 29 days each, 4 months of 31 days each and one month, Februarius (February) with 28 days, making a year of 355 days. The names of the 12 months of the Roman year were as follows:

Name of month	*Origin of name*
Martius	Month of Mars
Aprilis	"Opening" month, when the earth opens to produce new fruits
Maius	Month of the great god (Jupiter)
Junius	Month of the Junii (a Roman *gens* or clan)
Quintilis	Fifth month
Sextilis	Sixth month
September	Seventh month
October	Eighth month
November	Ninth month
December	Tenth month
Januarius	Month of the god Janus
Februarius	Month of the Februa (a purification feast)

In 153 B.C., January was designated as the first month of the year instead of Martius.

The Romans used a complicated system of reckoning within the month. There were three more or less fixed dates—the calends, the ides and the nones. (Our word "calendar" is derived from calends.) The calends always fell on the 1st of the month. The ides came on the 15th in Martius, Maius, Sextilis and October and on the 13th in other months. The nones always came on the 8th day before the ides. In designating a particular day of the month, Romans always reckoned backward from the calends, the ides or the nones, as the case might be. Thus the 15th of March would be referred to as the ides of March; the 14th as "the day before the ides of March"; the 13th as "the 3rd day before the ides of March" (more exactly, the 3rd day, counting backward, of the ides period).

The calendar was entrusted to a council of priests—the College of Pontiffs, presided over by a *pontifex maximus*. The pontiffs were not priests in our sense of the word; they were state officials charged with the regulation of certain religious matters. Among their duties was the fixing of dates for ceremonies and feast days. That is why the calendar was under their control;



This old Scandinavian calendar was made of wood.

and they flagrantly misused this power for their own selfish purposes.

Their corruption was most apparent in the way in which they inserted the thirteenth month, Mercedonius. Since there were no fixed rules for its intercalation, the pontiffs followed their own interests and those of their friends in the matter. They would sometimes insert Mercedonius in years where it did not belong in order to keep their friends longer in political office.

As a result, when Julius Caesar became virtual dictator of Rome, the calendar was in utter confusion.

Caesar was elected *pontifex maximus* in 63 B.C., but it was not until 47 B.C. that he took the first steps to reform the calendar. He called upon a famous Greek astronomer, Sosigenes, to undertake this momentous task. Sosigenes wisely counseled the Roman dictator that it would be futile to try to reconcile the old Roman moon-cycle calendar with the more scientific solar calendar developed by the Egyptians. Following the suggestions of Sosigenes, Caesar adopted the solar year for the Roman calendar; he gave it 365 days, plus a quarter-day of six hours. Quarter-days were withheld from the year until a full day had accumulated, the day was then added to the common year as a leap-year day. This happened once every four years.

Further changes had to be made to adjust the short moon year of 355 days to the 365-day sun year. Ten days had to be added to the year, of course; these were distributed among the various months. Seven months now had 31 days each and four months 30 days each February still had 28 days. It was also allotted the extra day

The Bettmann Archive

Aztec stone calendar of the fifteenth century.

every leap year; but instead of becoming the 29th day of February, as in our calendar, it became an additional 24th day. This repetition of the 6th day before the calends of March (March 1) gave rise to the name "bissextile [twice sixth] year" for what we now call leap year.

The year 46 B.C. bridged the old and the new calendar by having 445 days. Contemporary historians ruefully referred to it as the "year of confusion." The following year, 45 B.C., was actually the first one of this reformed calendar. Caesar retained the complicated system of calends, nones and ides within the months; January continued to be the first month of the year. The Roman Senate changed the name of

the month Quintilis to Julius (our July) in honor of Caesar. The new calendar, shown on page 3990, was known as the Julian calendar; it was used for many centuries after the downfall of the Western Roman Empire.

Caesar was assassinated in 44 B.C. After his death the pontiffs disregarded the leap year provisions that had been established by Caesar. They inserted a leap-year day every three years instead of every four; as a result the calendar again began to be out of step with the seasons. Augustus Caesar, the first Roman emperor, was compelled to correct the error by dropping leap-year days from 8 B.C. to 8 A.D. On 8 A.D. the leap-year series was resumed on the basis of one leap year in every four-year period.

To honor the Emperor Augustus, the Roman Senate changed the name of the month Sextilis to Augustus (August). This month had formerly had thirty days. The story goes that the Emperor persuaded the Senate to increase the number of days in August by one, so that his month would have as many days as July, named after Caesar. Some scholars hold, however, that Caesar established the length of the months as we know them before Augustus became emperor.

Constantine introduces the seven-day week

In 321 A.D. the Emperor Constantine issued an edict introducing the seven-day week in the calendar, doing away once and for all with the system of calends, ides and nones. Constantine established Sunday as the first day of the week and set it aside as the Christian day of worship.

There are three theories about the reason for the Emperor's selection of the seven-day week. Some scholars say that it is based on the story of creation in the Book of Genesis: the world, according to this account, was created in six days and a seventh day was set aside as a day of rest. Others believe that the number of days in the week was based on the number of the "planets" known at that time—Mars, Mercury, Jupiter, Venus, Saturn, the sun and the moon. (Of course, we know now that the sun is not a planet but a star and that the moon is a satellite of the earth.) Still others believe that the week originated with the phases of the moon, each being of about seven days' duration.

	S	M	T	W	T	F	S
JAN		1	2	3	4	5	6
	7	8	9	10	11	12	13
	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
	28	29	30	31			
FEB					1	2	3
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28 (29 in leap year)			
MAR					1	2	3
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	31
APR	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30					
MAY				1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31		
JUN						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30

	S	M	T	W	T	F	S
JUL	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31				
AUG				1	2	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18
	19	20	21	22	23	24	25
	26	27	28	29	30	31	
SEP							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
	30						
OCT		1	2	3	4	5	6
	7	8	9	10	11	12	13
	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
	28	29	30	31			
NOV					1	2	3
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	
DEC							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
	30	31					

The Gregorian calendar. It must borrow one or two days from another week to complete the year; hence it changes every year.

Although the introduction of the week greatly sim-

plified matters, it brought about a serious defect in the calendar. Both the Egyptian and Julian calendars had been stabilized: that is, in them every year had been like every other year. Through Constantine's reform the Julian calendar became a shifting one. Now that there were 52 seven-day weeks, totaling 364 days, there was always one day left over in ordinary years and 2 days in leap years. This meant that in successive years, the Julian calendar began on different days of the week Suppose that January 1 of a given year fell on a Sunday. The 30th of December would come on a Saturday; the 31st would be Sunday. The new year would begin on Monday and not on Sunday, as in the preceding year.

The Gregorian calendar

The true length of the solar year is a trifle less than 365 and a quarter days—it is 365.242199 days, or 365 days, 5 hours, 48 minutes and 46 seconds, to be exact. Therefore the Julian calendar was too long by about 11 minutes; after a number of centuries the error in question amounted to several days. Once again the calendar began to drift from its seasonal moorings.

In the year 1582 another momentous calendar reform took place. Pope Gregory XIII determined to adjust the calendar to the seasons; for this purpose he called upon the services of the mathematician Christopher Clavius and the astronomer-physician Luigi Lilio Ghiraldi, also known by the Latinized version of his name—Aloysius Lilius. They found that the error caused by the excessive length of the Julian calendar now amounted to ten days. To set the year aright, they canceled ten days from the Julian calendar, so that October 4, 1582, was followed by October 15. This was how the month looked on the calendar:

1582			OCTOBER			1582
SUN	MON	TUE	WED	THUR	FRI	SAT
	1	2	3	4	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Naturally this loss of ten days in the month of October created a certain amount of confusion. For example, according to the calendar, little Thingumbob, born on October 4, 1582, was eleven days old on the following day, the 15th! To avoid confusion, dates prior to October 15, 1582, were often given thereafter (and are still often given) as O S. (old style) or N.S. (new style). In the case of Thingumbob, his date of birth could be given as either October 4 (O.S.) or October 14 (N.S.). If neither O.S. nor N.S. is given after a date, the presumption is that it is N.S.

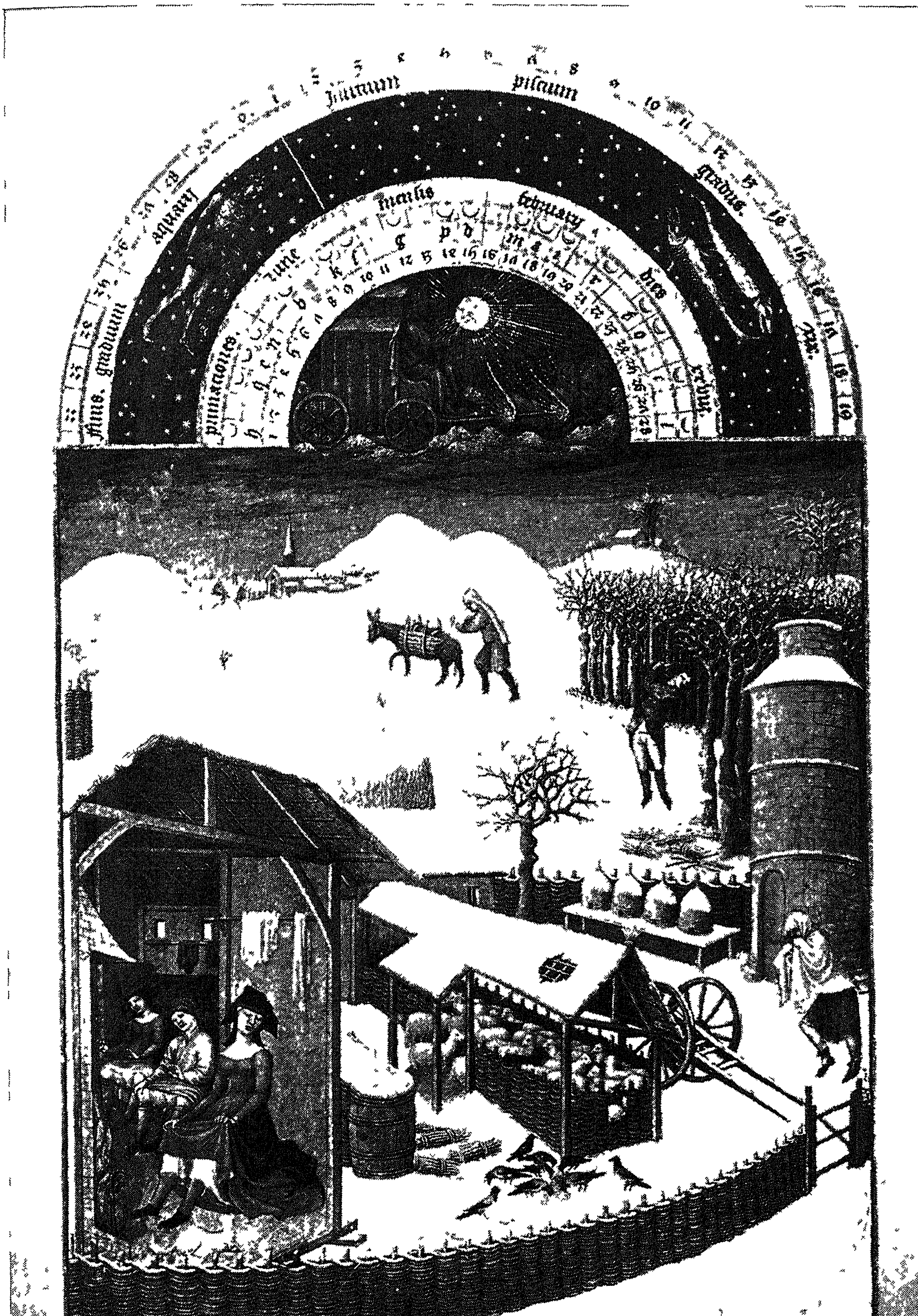
To avoid further error in the calendar, the leap-year rule was changed. In the case of centurial years (those ending in "00"), only the ones that were divisible by 400 were to be leap years. Thus, of the four centurial years since the establishment of the Gregorian calendar, 1600 was a leap year, while 1700, 1800 and 1900 were not. Non-centurial leap years continued to receive an extra day. The year still began on January 1. No attempt was made to equalize the lengths of the months or to stabilize the calendar. This Gregorian calendar is the one that we use today.

All Roman Catholic countries adopted the Gregorian reform, but other groups in Christendom were slow in accepting it. The English kept on using the Julian calendar for over a century and a half; they did not adopt the Gregorian calendar until 1752 In doing so, they had to cancel eleven days instead of ten, because the year 1700 was a leap year in the Julian calendar, but not in the Gregorian. The eleven lost days were canceled in September, thus:

1752			SEPTEMBER			1752
SUN	MON	TUE	WED	THUR	FRI	SAT
		1	2	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

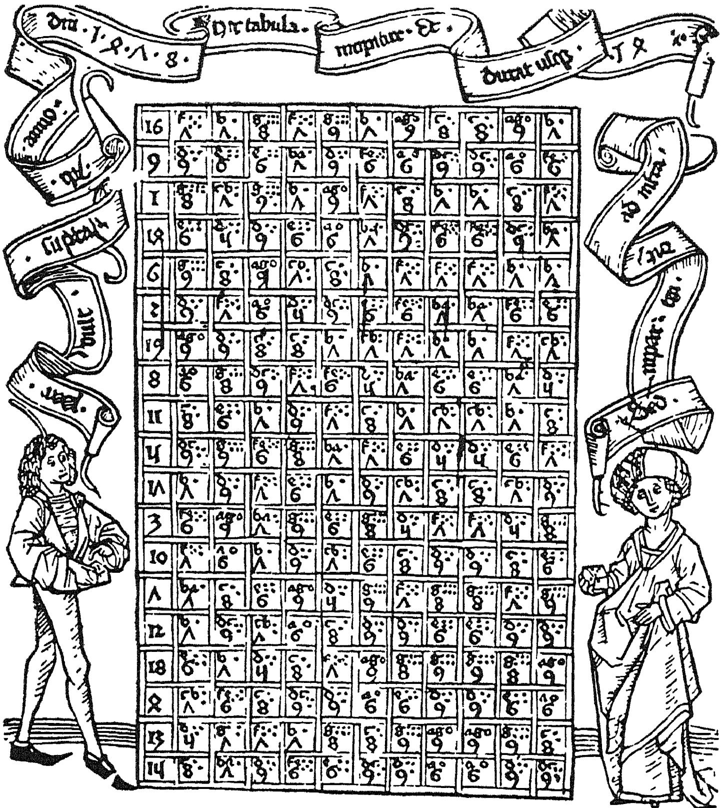
France, like the other Catholic countries of Europe, had adopted the Gregorian calendar in 1582. But in the course of the French Revolution, the legislative body known as the National Convention issued a decree (November 24, 1793) providing for a new calendar. In this, the year was to consist

A FAMOUS MEDIEVAL CALENDAR



Conde Museum, Chantilly

The month of February in the Book of Hours, a masterpiece that goes back to the fifteenth century.



The Bettmann Archive

This medieval calendar enabled readers to calculate the holidays.

of 12 months with 30 days each; to complete the full number of days, 5 feast days (in leap years, 6) were to be added at the end of the year. The new reckoning was to begin with September 22, 1792, when the first decree of the new French Republic had been issued; the date corresponding to September 22 was to be the first day of the year I. This calendar was abolished, at the command of Napoleon, by a decree of the Senate on September 9, 1805; the Gregorian calendar was re-established on January 1 of the following year.

Japan adopted the Gregorian calendar in 1873, China in 1912, Greece in 1924 and Turkey in 1927. Russia began to use the calendar in 1918, replaced it by a calendar of her own when the Bolsheviks took over the country and returned to the Gregorian calendar in 1940.

The Gregorian calendar is not the only one used at the present time. For religious purposes Jews employ the Hebrew calendar, which begins with the year of creation, set at 3,760 years before the beginning of the Christian Era. This calendar is based on the cycles of the moon; there are 12 months, which are alternately 29 and 30 days in length. An extra month of 29 days is intercalated 7 times in every cycle of 19 years; whenever this is done, one of the 29-day months receives an extra day. The year begins in the autumn.

Another important calendar is the Islamic, or Mohammedan, calendar. It also is based on the cycles of the moon; there are 354 days and 12 months, half of which have 29 days and the other half 30. Thirty years form a cycle; 11 times in every cycle an extra day is added at the end of the year. The months and the seasons do not correspond; the first day of the Moslem year falls on different seasons in different years. The Mohammedan calendar begins with the first day of the year of the Hegira—that is, the flight of Mohammed to Medina. This date corresponds to July 15, 622, of the Christian Era.

Modern calendar reform

The Gregorian calendar has served man and served him well for almost four centuries. Yet some thoughtful people have not been satisfied with it; they have tried to bring about reforms that would restore stability to the calendar within the framework of the seasonal year and at the same time rearrange it on a more orderly and practical basis.

In 1834, Abbé Marco Mastrofini, a Roman Catholic priest, put forward a plan by

which every year would be perpetually the same and the lost stability of the calendar would be restored. In his calendar, there were 364 days in the year—a number easily divisible in various ways. The 365th day and the 366th, in leap years, were inserted as extra days within the year. Each year would begin on Sunday, January 1. The Abbé's idea was so simple and practical that most modern calendar reformers have made it the basis of their own proposals.

Calendar reform lagged until the League of Nations took up the question in 1923. Acting upon a request made by the International Chamber of Commerce in 1920, the league turned over the matter of calendar reform to its Advisory and Technical Committee for Communications and Transit. A preparatory meeting was held at Geneva in June 1931; and in October of that year a full-fledged international Conference on Calendar Reform took place.

More than 500 plans were submitted to the conference. Some of these were based on the decimal system; others, on a 5-day, 6-day or 10-day week. One project introduced 4 long 35-day months and 8 short 28-day months; another, a 364-day year, with occasional "leap weeks" added every 5, 6 or 11 years. Of all the plans submitted to the conference, only 2 received serious consideration. These were the Thirteen-Month Calendar and the World Calendar. Both plans called for intercalated or extra days; both conformed to the seasons.

Each of the 13 months in the Thirteen-Month Calendar has 4 weeks each; there are 13 weeks in each quarterly season. That makes a total of 364 days. To bring the total up to 365, a "year day" is added, corresponding to December 29. The names of the 12 months of the Gregorian calendar are kept; the thirteenth month, set between June and July, is called Sol. The Thirteen-Month Calendar is shown on this page.

This calendar met with serious objections. Americans were unwilling to accept a calendar in which their Independence Day would come, not on the traditional date of July 4, but on Sol 17. Businessmen complained that it would complicate matters for them; that, for example, they would have to issue statements to all their customers thirteen times a year instead of twelve times. As a result the Thirteen-Month Calendar is now no longer seriously considered as a successor to the Gregorian calendar.

But the World Calendar, based on the easily divisible number 12, has become increasingly popular. In this calendar each

JANUARY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

FEBRUARY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

MARCH

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

APRIL

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

MAY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

JUNE

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

LEAP DAY
June 29

SOL

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

JULY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

AUGUST

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

SEPTEMBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

OCTOBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

NOVEMBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

DECEMBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

YEAR DAY
DECEMBER 29

The Thirteen-Month Calendar. Each month has 4 weeks and 28 days. There is also a Year Day and, in leap years, a Leap Day.

equal quarter year of 91 days, or 13 weeks or 3 months, corresponds to a seasonal period. The three months within each quarter-year have respectively 31, 30 and 30 days; every month has 26 weekdays plus Sundays. Every year in this calendar is like every other year; the first of every year, for example, falls on a Sunday; Christmas, December 25, falls on a Monday.

Since each quarter-year consists of 91 days, the total number of days in all four quarter-years is 364. To provide the necessary 365th day, another day—known as Worldsday—has been inserted. It is placed after December 30 and before January 1; it belongs to the month of December. Worldsday is a world holiday.

The 366th day in leap years is inserted between June 30 and July 1; it is called Leapyear Day and is also considered as a world holiday. Worldsday and Leapyear Day are dated respectively December W or December 31 and June W or June 31; the letter "W" is preferred. These two stabilizing days keep the calendar on an even keel with the seasons. The Gregorian four-hundred centurial leap-year rule is retained. In fact, the World Calendar differs but little from the Gregorian calendar; the two are identical for the period between September 1 and February 28, bearing in mind, of course, that Worldsday, December W, is equivalent to December 31. The World Calendar is shown on this page.

In 1937, when the League of Nations asked the different member and non-member nations to give their opinion of the World Calendar, 14 nations approved it, 6 rejected it, 8 abstained from replying, 10 said that they were not prepared to reply and 7 believed that the time was premature for a new calendar. The result was considered unsatisfactory; besides the league felt that so momentous a step as the introduction of a world calendar should not be taken with political conditions as unsettled as they were throughout the world. (Continued Axis aggression had brought about great tension.) Therefore the new calendar was set aside. It has been revived in the United Nations and has received a great deal of support in that body.

FIRST QUARTER

JANUARY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

FEBRUARY

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

MARCH

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

SECOND QUARTER

APRIL

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

MAY

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

JUNE

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
						**W

THIRD QUARTER

JULY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

AUGUST

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

SEPTEMBER

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

FOURTH QUARTER

OCTOBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

NOVEMBER

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

DECEMBER

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
						*W

The World Calendar. The W with a single asterisk before it is Worldsday; the W that has two asterisks before it is Leapyear Day.

PROBLEMS OF STAR LAND

Star Color and Color Changes—Increase and Subsidence of Brightness—Unexplained Comings and Goings

WHAT DARK STARS RANGE THE SKY UNSEEN

EVEN to the unaided eye, many of the stars display beautiful tinges of color, and especially of red. But these colors are enormously increased in splendor and beauty by the telescope, which also reveals the delicate tints of many stars that otherwise appear white. The most deeply colored of all first-magnitude stars is Antares, which is of a wonderful ruby red. Successively somewhat less deep and rich in tone, though of the same color, are Betelgeux, Aldebaran and Arcturus. Ptolemy includes in his list of fiery red stars, besides the four we have mentioned, Pollux and Sirius, neither of which could now be classed as red. The light of Pollux is indeed inclined to yellow, but Sirius, as we have seen, is of a cold, dazzling, bluish-white. Have these stars, then, changed in color?

Some authorities have disputed the genuineness of Ptolemy's inclusion of Sirius in his list, and maintain that the name has crept into the text by the error of a copyist. There is a good deal to be said for this view, for a later writer mentions five as the number of red stars catalogued by Ptolemy. But the imputation of color to the Dog Star seems to be of wider occurrence in ancient literature than justifies us in rejecting it as altogether baseless; among others. Homer, Seneca, Cicero and Horace refer to it as red, and the impression of its fiery glare seems to have been general. No one could now call Sirius a red star; nor does it seem likely that its red color persisted beyond the early centuries of our era, for in all the many works of Arabian astronomers of the tenth and later centuries there is no suggestion that the star was at that time colored. It is, on the whole, likely, then, that we have here an example of real color change, and that Sirius actually had, in ancient times, a ruddy and lurid appearance which it has since utterly lost.

This is the more probable because there are other examples of color change which appear to be duly authenticated; yet it must always be a difficult matter to determine these alterations of tint until some scientific means has been discovered for registering and comparing the colors of stars. Innumerable difficulties have, so far, beset any attempt to record these colors with any certainty, because no two observers can be sure that they see colors exactly alike, and even the two eyes of one individual may perceive different colorings in the same object. Again, it has often been found that different people use various terms to describe the same color, and intend different colors by their use of the same term. So it is that differences in instruments, in atmospheric conditions and in all kinds of personal factors make it impossible to eliminate, at the present stage of science, a large amount of error and of subjective disagreement.

Yet some examples of color change seem, as we have said, to be sufficiently attested. Algol, the Demon Star, in the constellation of Perseus, is noted by Al Sufi, the Persian astronomer, as a red star, but is now pure white. It may be that Algol, which is a celebrated variable star, assumes at times a temporarily red hue; for in modern times the astronomer Schmidt saw it once, in 1841, of a yellowish-red color, but on all later occasions he found it white. Other cases are on record, of which T. Ursæ

Majoris and S. Cephei are among the best known. All of them change between red and white, and it is in red stars alone that this tendency to vary in color is found, just as it is in red or reddish stars that variations in magnitude are chiefly found.

Much more beautiful and impressive, however, though only visible by means of the telescope, are the pairs of colored stars which are by no means uncommon in the heavens. Stars which to unaided vision seem but a single point of more or less doubtful color reveal themselves in the telescope as pairs of stars, displaying amazingly lovely harmonies of color, either contrasted or graded. Moreover, real changes of color seem also to be fairly common in these pairs. A very beautiful pair, known as 95 Herculis, have been seen by many observers in contrasted tints of green and red — "apple-green and cherry-red"; but there are also authentic records of their having been seen, on various occasions, respectively green and yellow, gold and azure, bluish-white and reddish, greenish-yellow and reddish-yellow, and again both white, while at present they are both of a delicate primrose tint.

Instances of companion pairs of stars that tone beautifully in color

Color changes of this nature may occur in equal pairs, or in unequal pairs consisting of a primary and a satellite; in the latter case the satellite frequently varies, while the primary remains constant in color. But the contrary never occurs; there is no case of a primary subject to change in color while its satellite remains constant.

Beautiful instances of colored pairs are found in a star in Andromeda, where one of the pair is orange and the other green; a star in Cassiopeia, one yellow and the other rose-color; in Cepheus, with one orange and one purple; another pair in the same constellation, gold and azure respectively; a pair in Cygnus, similar to the last; Delphinus has a pair, yellow and emerald; Draco includes another, of which one member is orange and the other emerald; a wonderful pair in Serpens are sea-green and lilac respectively; Virgo has a colored pair, of which one is light rose and the other dull red; and other various examples might be given. Very delicately lovely effects are produced by the not uncommon juxtaposition of a bright white star with a small blue or lilac star. Rigel and Regulus, brilliant white stars, have attendants of azure, indigo, lilac or amethyst shades.

Stars that vary, some regularly, some irregularly, in brilliancy

It has been noted that stars which vary in color are usually subject to changes in magnitude. These changes in brilliancy are more open to exact observation than the changes in color, and some knowledge has already been obtained of the nature of their causes. Many thousand stars of unquestioned variability are now known; some of them vary in no definite periods, but altogether irregularly; others vary in regular periods, the shortest periods being a couple of hours and the longest a couple of years in duration.

Stars with regular periodic fluctuations in magnitude range themselves into two quite distinct classes, according to whether the periods of change are long or short. Long-period variables have periods usually between one hundred and fifty and four hundred and fifty days, though the period may in this class be as short as four months or as long as two years. Short-period variables, on the other hand, have periods of less than fifty, and, indeed, usually less than ten days. There are a few stars with periods intermediate between those of the two classes, which form gradations between them; but the two classes are physically distinct, and their variations are due to different causes.

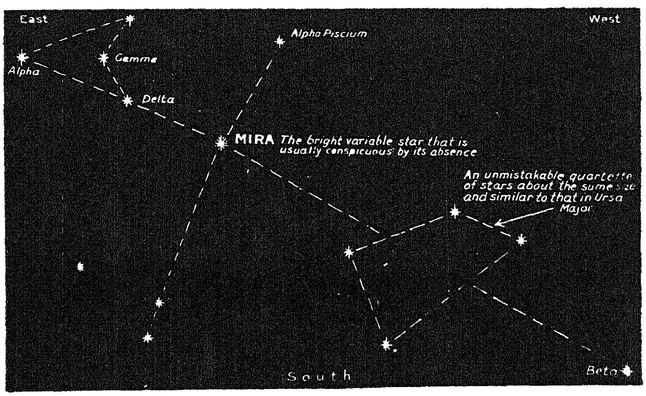
The most famous of the long-period variables, and the first one discovered, is Mira, in the constellation Cetus. It was first noticed by David Fabricius, a Frisian pastor, in 1596, but was then taken for a "nova".

The "wonderful" star that varies between the first and tenth magnitudes

It was found again on December 16, 1638, by John Holwarda, a Dutch professor of philosophy, who at first thought it was a nova; but he discovered its true

character as a periodic variable when it again reached its maximum early in November, 1639. In 1667 Bouillau assigned to it a period of three hundred and thirty-three days. But its periods are subject to considerable irregularity, so that neither the maximum nor the minimum brilliancy can be determined beforehand with any precision. Either may be hastened or retarded by a week or two, and occasionally as much as forty days, from its appropriate time; and there seems to be no order or rhythm in the occurrence of these digressions. Neither is there any regularity in the intensity of the light-variations. The maximum brightness has been known to attain nearly to the first magnitude, for Sir W. Herschel noted Mira in 1779 as almost equal in brilliancy to Aldebaran, a standard first-magnitude star; but at other times it fails even to attain, at its greatest brightness, to the fifth magnitude. Its minimum, though on the whole more uniform, is also subject to irregularity; it usually falls to between the ninth and tenth magnitudes, but has been known to descend considerably lower than this. In 1783, for instance, Sir W. Herschel could find no trace of it with a telescope in which all stars down to the tenth magnitude were visible. If we consider the whole range within which the brilliancy of Mira has been recorded to vary, we find that the light emitted by it at certain periods is about ten thousand times as much as the light emitted at other periods though in its usual range of brilliancy it is only twelve or fifteen hundred times brighter at maximum than at minimum.

The occurrence of these variations in brilliancy pursues a course more or less as follows. At intervals of about eleven months the star begins to brighten, and rises from below the ninth magnitude to a maximum which varies, as we have seen, but often reaches the second magnitude. This is accomplished in about one hundred and ten days, and the star then remains for two or three weeks in the glory it has attained; it then subsides to its former low estate, taking about twice as long in the descent as in the ascent. In point of fact, this star is perpetually in process of change; but for ordinary observation it may be said to remain at a high level of brilliancy for about two months, and at a low level of brilliancy for about three months, spending the rest of the time in changing from one level to the other.



MIRA, THE LONG-PERIOD VARIABLE STAR IN CETUS

Mira will be found by this diagram of the larger stars, in the south from 9 P.M. to 10 P.M. in October and November, and an hour or so earlier in December

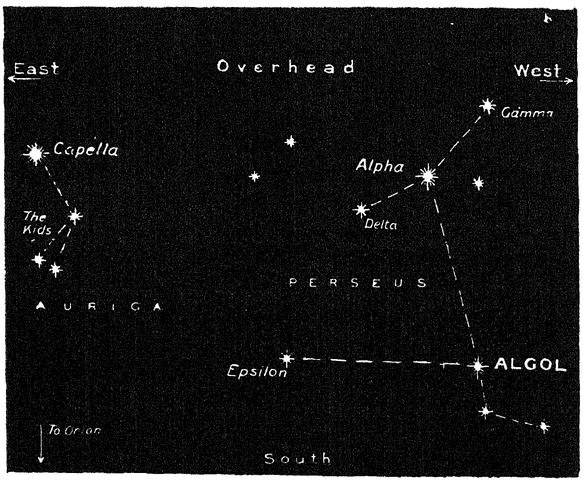
Another famous long-period variable is Chi Cygni, which shines at its maximum with more than six thousand times its minimum brilliancy, rising and falling in periods of four hundred and six days through nine and a half magnitudes. The period of this star, which is of a beautiful scarlet color, has lengthened with fair regularity by about a quarter of an hour each time since its first recognition in 1686.

These two stars show exceptionally large ranges of fluctuation, for the average amount of variation in seventy-five long-period variables which have been kept under close observation at Harvard has been found to be five magnitudes, which means that the star gives out one hundred times more light at maximum than at minimum.

Spectroscopic examination has shown that these fluctuations in light are accompanied by definite physical changes. The increase of brilliancy is caused by periodical outbursts of incandescent gases, chiefly hydrogen, in the variable star. Further, the curves of the variation of light in

long-period variables are found to be closely similar to the curve of the frequency of sun-spots in our sun. The physical causes of the two phenomena are probably of the same kind, though their apparent results are so different. The points of similarity in the curves of sun-spot frequency and of the variation of light in a star such as Mira are noteworthy. In both, the rise is much more rapid than the fall; and both show a check in the descent, with an attempt at a second maximum, thus giving the curve the appearance of a double peak, of which one point is considerably higher than the other. These variable stars at their greatest brightness show bright lines in their spectra, indicating blazing gases; and we know that the corona of the sun emits a greatly intensified light at the periods when sun-spots are most frequent. It is true that no variable star has yet been discovered with a period corresponding in length to that of the frequency of sun-spots, but this, again, is only a difference of degree and not of kind. The two phenomena seem to be closely related, and any discoveries in connection with the occurrence of sun-spots may prove to shed considerable light on the nature of the fluctuations in long-period variables.

Stars of this class are almost all red, and show bright lines of hydrogen in their spectra. In addition to those which we have already named, the following deserve special notice. R Hydræ is a variable with a period which grows shorter at each recurrence, so that from five hundred days in 1708 it had become four hundred and twenty-five days in 1891 — a red star which rises nearly to the third magnitude. S Ursæ Majoris, recognized as a variable in 1853, has a mean period of two hundred and twenty-six and a half days which, however, lengthens and shortens by a succession of irregularities which repeats itself every sixty-seven years. This star is deep red in its lower phases, but at its maxima sometimes becomes almost white. T Ursæ Majoris, a dull red star with a period of about three hundred and two days is also subject to irregularities of many kinds. R Leonis, a beautiful star of glowing red, varying from the fifth to the tenth magnitude, has a period which is gradually shortening, but is too complicated for exact estimation; it is somewhat less than three hundred days



ALGOL, A SHORT-PERIOD VARIABLE STAR

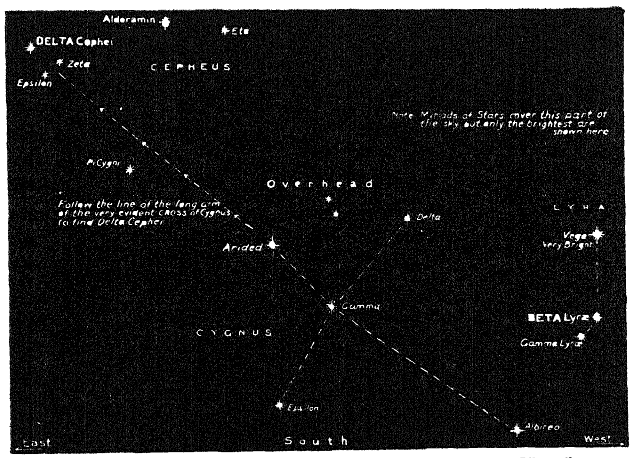
Algol is nearly overhead in November, December, and January, and towards the N E before and the N W. after these dates.

The process of change in the short-period variable stars is in many ways quite distinct from that of long-period variables. In the first place the fluctuations are regular, rising and falling in orderly rhythm; and, secondly, the changes are of smaller range, the total variability rarely extending over more than two magnitudes.

Variable stars may be divided into two groups: the periodic and the non-periodic. The first group includes eclipsing variables, which are recognized by the form of their light variations; variable stars with a short period, ranging from a few hours to about two months; and long-period variables, which require from about four months to two years to complete their change. The second group includes irregular variables, and the novæ.

Algol variables, or "eclipsing stars", are marked by periods of precise regularity. The light is constant during the greater part of the time, but at regular intervals suffers a certain unvarying diminution. It is at once clear that these changes represent a periodical eclipse of the luminary

by a companion passing between it and us, in the course of a regular orbital motion. Such systems are of very great interest, because they are open to a considerable amount of investigation Thus, if there are two equal and equally luminous bodies, there will be two equal minima, or eclipses, in each period; but if one of the two equal bodies is dark, there will be only one eclipse in the period. We can tell by spectroscopic examination whether a period includes one eclipse or two equal eclipses, for the spectroscope reveals the direction of motion of the luminaries If, again, there are two unequal bodies, or two bodies of unequal luminosity, this will be shown by the occurrence of two unequal minima in each period. Where there is one small bright star and another large but only slightly luminous star, we get a prolonged and low minimum brightness, the occultation of the darker by the brighter star being hardly marked by any change in brilliancy.



VARIABLE STARS — BETA LYRÆ AND DELTA CEPHEI

These stars are almost overhead in summer and autumn, and towards the west overhead after October To identify them, face south with diagram and look up.

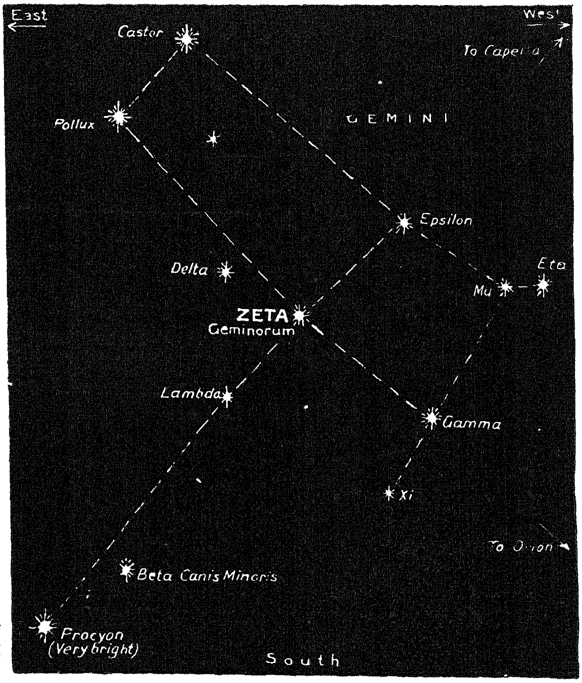
It is obvious that these short-period variable stars are not distinguished by any physical peculiarities from other binary systems of stars; their eclipses, or regular variations in light, are due only to the fact that their motion around one another takes place in the plane of our vision, and are determined by our position in space relatively to their movements.

Algol, the typical star of this class, was probably known as a variable in ancient days; so, at least, we may judge from its name which signifies "the demon", suggesting some preternatural fire or spirit observed in its shining. The nature of its fluctuations was discovered in modern times by John Goodricke, a deaf-mute of York, in 1783, who also suggested the true explanation of these changes. Since that time Algol has been observed with great care, and much has been learned of its system. This consists of a light and a dark body. The primary star is a brilliant sun of the helium type, and around it revolves a huge companion with very little luminosity. The primary star is just over one million miles in diameter — that is to say, once and a quarter times the diameter of our sun. The size of the faint companion star is not so easy to compute with accuracy, because its center does not pass exactly across that of the primary. The late Professor Hermann Vogel, basing his calculations on the supposition that the companion star was entirely dark, estimated its diameter at eight hundred and thirty thousand miles, and calculated that the distance from center to center of these two enormous globes is probably not more than three and a quarter million miles, so that their surfaces are within less than two and a half million miles of one another. More recent observations with improved photometers by Professor Joel Stebbins and others showed that there is a secondary minimum in the light variation: this proved that the faint companion was not entirely dark as previously supposed but that it had a luminosity of about seven-hundredths of the intensity of the bright star. This required a new estimate of the dimensions of the system and it was found that the diameter of the faint companion was about one-seventh larger than the diameter of the bright star and that their surfaces are separated by a little more than 3,500,000 miles. Such close proximity seems almost incredible in view of the stability with which they are

known to retain their relative positions and motions. But this near neighborhood is apparently not uncommon in stellar systems; we find huge luminaries retaining their mutual relations unimpaired for ages in even closer proximity than this.

Variable stars of the type of Beta Lyræ have no interval of constant luminosity within their period; they present a continuous, rhythmical series of fluctuations. The light-curve shows two equal maxima, separated by two unequal minima.

The two other types of short-period variables—those which follow respectively Zeta Geminorum and Delta Cephei—are in constant process of light-variation, but differ in respect of the details of the process. In the Geminid stars, as they are called, the variations from maximum to minimum and from minimum back to maximum are symmetrical and occur in equal periods of time; but in Cepheid stars the variation in brightness is very unsymmetrical, though the entire range of variation is accomplished with the same regularity of period as in the other cases. The total period of Delta Cephei from minimum to minimum occupies nearly five and a half days, and the light varies during this time from the magnitude of 4.6 to that of 3.7, and down again. It takes, however, only one and a half days to accomplish its rise, the descent occupying four days and not being accomplished with the regularity that marks the rise. About fifteen hours after the turn there is a halt in the descent, and the star remains stationary in brilliancy for a short time before resuming its declining course. The curve of light-change is, in fact, very like the curve of sun-spot frequency and of long-period variables. It is known by spectroscopic means that the light-minima in the Cepheid variables do not represent eclipses or occultations, and that in these variables changes occur in brightness, color and spectra in such a related manner as to make it probable that the surface temperature changes. An ingenious theory, first proposed by Harlow Shapley, and developed mathematically by Eddington, assumes a periodic expansion and contraction of the star under the combined influence of gravitation and the gases of which it is composed. This pulsation theory, as it is called, accounts for most of the observed phenomena. A normal star, such as our sun, is in equilibrium because the pressure due to the weight of overlying layers is, at any point, balanced by the pressure of the radiation from its incandescent gases. If, by some external means, the star were to undergo a compression so that its radius became shortened by some ten per cent, gravitational pressure would increase at any point. However, the compression would have resulted in the gas being heated, and hence the gas pressure would also be greater. Mathematical consideration of this problem shows that the gas pressure would be the greater of the two, and that the star would tend, as a result, to resume its original state through expansion. In the process of restoration



ZETA GEMINORUM, A SHORT-PERIOD VARIABLE
This star will be found almost overhead, towards the south, in January and February, towards the east in December, and towards the west in March.

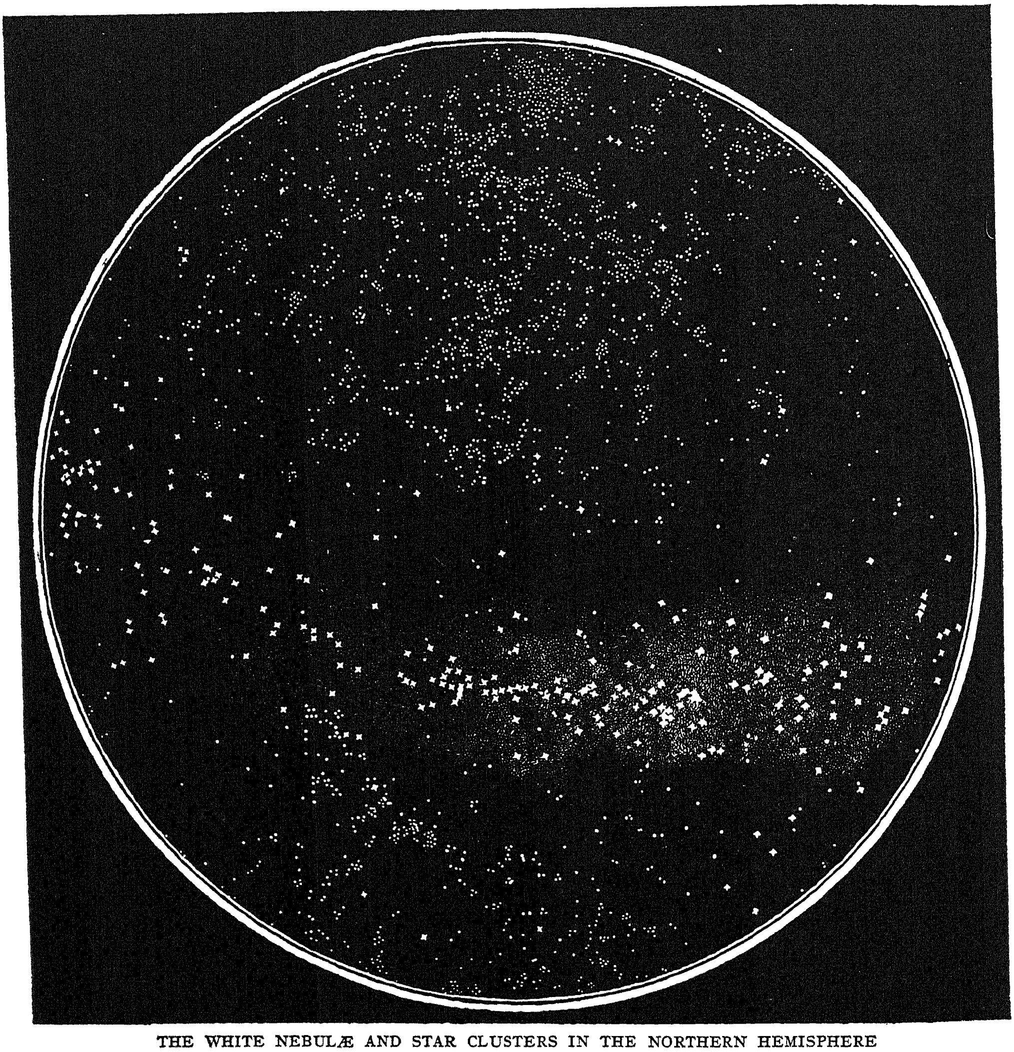
THE EARTH WAS VOID & WITHOUT FORM"

A PART OF THE NEBULA OF RHO OPHIUCHI, SHOWING DARK LANES
From a photograph taken by Edward E. Barnard at the Mount Wilson Observatory

to its initial size, the inertia of the expanding gas would carry it beyond the position of equilibrium until a state had been reached at which the gas pressure was too low internally, and now the gravitational forces would preponderate and cause the star to contract. Here, again, the contraction would not stop at a point of stable equilibrium, but would continue beyond. The disturbance which we assumed to throw the star out of its original state of equilibrium, would thus start a series of pulsations which would continue in effect even when the originating cause was removed.

The relationship between the brightness and period of Cepheid variables

Early in this century, a new and powerful method for sounding the depths of space was discovered by Miss Henrietta S. Leavitt, of Harvard University, as a result of a study made by her of the Lesser Magellanic Cloud, a star-cloud in the southern heavens rich in variables. As the surrounding sky has few variables, it was assumed that those in the Magellanic Clouds were members of that group, and at approximately the same distances from the earth. When



THE WHITE NEBULÆ AND STAR CLUSTERS IN THE NORTHERN HEMISPHERE

In this diagram, plotted on equal surface projection, the nebulæ, largely double spiral, are represented by dots and the star clusters by crosses. The belt is the Milky Way, which contains the bulk of ordinary stars. The number of visible nebulæ increases towards the poles.

Miss Leavitt had suitably arranged these Cepheids according to their period and brightness, she found that a definite relationship existed; that Cepheids with closely similar periods had closely similar brightnesses; and that given the period of any Cepheid in the Cloud its brightness could be predicted with fair accuracy. The conclusion that Cepheids with given periods were alike in other respects also, was borne out by Shapley's investigations of variable stars in globular clusters. This relationship made it possible, given the distance of one Cepheid, to be able to compute the distances of all other Cepheids and the groups to which they belonged. Astronomers determined the distances of several of the brighter Cepheids found in the sky at large, and by using these results were enabled to calculate the distances of other Cepheids on the basis of the period-luminosity relationship.

The light received from a given source at a given distance will be four times as great if we halve the distance, and only one-fourth as great if we double the distance; or, to state the matter in a more general and mathematical way, the amount of light received will vary inversely as the square of the distance from the source. Thus we know that if the magnitude of a Cepheid with a 4.6 day period is 14, it is 100 times more distant than another Cepheid with a similar period and a magnitude of 4. The difference between the magnitudes indicates that the dimmer star is 10,000 times less bright than the other, and hence, according to the inverse square law of the intensity of illumination, is 100 times as distant. These Cepheids of magnitudes 14 and 4, and with like periods, are assumed by the period-brightness relationship to have the same intrinsic brightness, and hence the difference in observed magnitudes shows a difference in distance from us.

Some famous examples of brilliancy and decline in stars

In a minor degree such accessions of brilliancy, single and unaccountable, are not uncommon, but we need only notice the famous examples. Instances of such phenomena are on record from early times, and most of them were apparently genuine new stars. Among those quoted by Miss Clerke in "The System of the Stars" are the "novæ" of 134 B.C. in Scorpio, known as the star of Hipparchus; 123 A.D., in Ophiuchus: 173 A.D. in Centaurus visible for eight months; 386 A.D. in Sagittarius; 389 in Aquila, rivaled Venus in brilliancy, but vanished in three weeks; 393 and 827, both in Scorpio; 1012 in Aries; 1203 in Scorpio; 1230 in Ophiuchus; 1572, Tycho's star in Cassiopeia; 1604, Kepler's star in Ophiuchus; 1670 in Vulpecula. With the nineteenth century, and especially since the application of photography to astronomical research, they become more numerous. One of the most famous of recent years was Nova Persei, discovered by Dr. Thomas D. Anderson, of Edinburgh, on February 22, 1901, which in two days became the brightest star in the northern heavens, having increased its original brightness 20,000 fold in four days: it then gradually decreased in brightness until after two years it had declined to the twelfth magnitude, at which it then remained constant. Another example occurring in recent years is Nova Aquilæ No. 3, which from being an eleventh-magnitude star suddenly rose in brilliancy, reaching its maximum on June 9, 1918, when it was ten times as bright as a first-magnitude star or over 60,000 times brighter than before the outburst. Late in November, 1942, a brilliant nova was discovered in the constellation Puppis, which has been tentatively classed among the supernovæ.

The radiantly brilliant new star which Tycho Brahe discovered

It will at once be noticed that special regions of the sky alone seem to produce new stars, and almost all the positions in which they have been observed lie in the Milky Way. The most famous of all these apparitions is that known as Tycho's star, in Cassiopeia. It was carefully observed by Tycho Brahe throughout its course. He noticed it as a "stranger star" on November 11, 1572, though it had been seen by other observers two or three days previously. At first of a radi-

antly white color, it shone in magnificent splendor, passing from equality with Jupiter to a brilliance surpassing even Venus. It was so bright that it could be seen on cloudy nights when no other star was visible, and some observers discovered it even in the full light of noon. But its splendor was short-lived. After about three weeks it began to fade, shone redly, but still noticeably for some time longer; then became dimmer, so that from May, 1573, its color was "pale with a livid cast", and in March, 1574, it disappeared. Even now it has not passed into utter darkness, but lingers on, a feeble eleventh-magnitude shadow of its former self. The history of most novæ is more or less similar to this.

Various explanations offered as to nature of sudden outbursts of luminosity

Little is so far actually known as to the nature of these brief and sudden outbursts of brilliant luminosity. One suggestion, which has been made at different times and which is graphically expressed by Miss Clerke, is to the effect that "stars in the Milky Way occasionally get entangled in the diffuse nebulosities with which that region abounds, and blaze through the resistance offered to their motion, just as meteors kindle to brief splendor in shooting athwart our cloud of circumfluous air".

It is impossible with our present knowledge, however, to apply this general explanation in any satisfactory manner. Others have suggested that a nova is the result of an impact or grazing encounter of two dark stars, or of the encounter of a vast swarm of meteorites with a nebula. What seems a very probable explanation has been suggested by W. H. Pickering, who thinks that the great increase in brilliancy is due to the sudden enlargement of the radiating surface of the star brought about by the collision of a planetoid with the star; the planetoid, in virtue of the gravitational attraction of the star, would at the moment of impact have a velocity of some 400 miles per second; it would pierce the outer envelope of gas before it would have a chance to vaporize and would explode within the photosphere of the star, thus scattering a vast amount of photospheric material of intense brilliancy over a very wide area. On this hypothesis the tremendous liberation of energy involved in the luminous outburst of a nova is not due directly to the transformation of the mechanical energy of motion into heat and light energy by the collision, but is almost entirely due to the sudden liberation of a large amount of the stored-up energy of the star itself, the radiation which takes place in a few days from the newly exposed and greatly enlarged surface being equal to the ordinary radiation from the normal surface of the star during a period of hundreds or even thousands of years. The dispersed material will rapidly cool and before long the brilliant nova will sink back to its previous inconspicuous condition. This suggestion seems in several ways to satisfy better than the other explanations so far offered the actual phenomena of observation, but we must confess that as yet we have no certainty as to the cause or the causes of the novæ.

Early in 1941, Fritz Zwicky advanced a new theory as to the structure of supernovæ (the brightest of the "new stars") after collapse following their explosion. He suggested that the end result of such an explosion is a star composed of neutrons, and of such extreme density that light could not escape from it, due to its intense gravitational pull—hence it would be invisible. But by the same token, the light from distant stars behind this neutron star would be bent by the lens action of its gravitational field in accordance with Einstein's theory, so that the image of the stars behind would appear as one star between the neutron star and the earth. Spectrum analysis of the light from this image would show it to be a combination of different types of stars and thus not a real star.

The Twentieth Century (1895-) VIII

by JUSTUS SCHIFFERES

THE MAKING OF A SCIENTIST

SOME young people who read these pages may find themselves drawn to a career in science. As scientists they will find themselves in most distinguished and also most varied company. As the preceding chapters of this group reveal, men and women of different races, walks of life, temperaments, creeds and professions have become famous scientists. Leonardo da Vinci was an artist; Sir William Herschel, a band leader; Lavoisier, a tax collector; Priestley, a clergyman; Marie Curie, a political exile; Joule, a brewer; Edison, a telegraph operator; Ruth Benedict, a teacher of English; Scheele, an apothecary; Einstein, a patent-office clerk; Faraday, a bookbinder; Halley, a gourmet; Newton, a recluse; Von Humboldt, an explorer; Leeuwenhoek, a lens-grinder; Pascal, a child prodigy; Darwin, an unpromising lad; Paracelsus, an alchemist; Kepler, an astrologer; Carver, a slave.

These men and women had in common their passionate devotion to science. The career of the great Negro chemist George Washington Carver offers a particularly striking example. It illustrates the important point that anybody with the necessary ability and the necessary ambition can become a first-rate scientist, no matter how humble his origin or how discouraging the circumstances under which he must work.

Carver was born of slave parents toward the close of the American Civil War (about 1864). His mother lived on the plantation of Moses Carver near the village of Diamond Grove in the extreme southwest corner of Missouri, not far from the Arkansas line; his father belonged to a neighboring farmer. One night slave raiders from Arkansas carried off little George and his mother from the Carver plantation. Moses Carver followed the raiders over the state line and ransomed George for a race horse worth about $300. The whereabouts of the child's mother remained unknown.

After the defeat of the South and the freeing of the slaves, George continued to live on the Carver plantation, which had been devastated by Union troops in the war. Since he was extremely frail, he did women's work about the house — he washed, ironed, cooked and sewed. A bright lad, he memorized a little blue-backed Webster's speller.

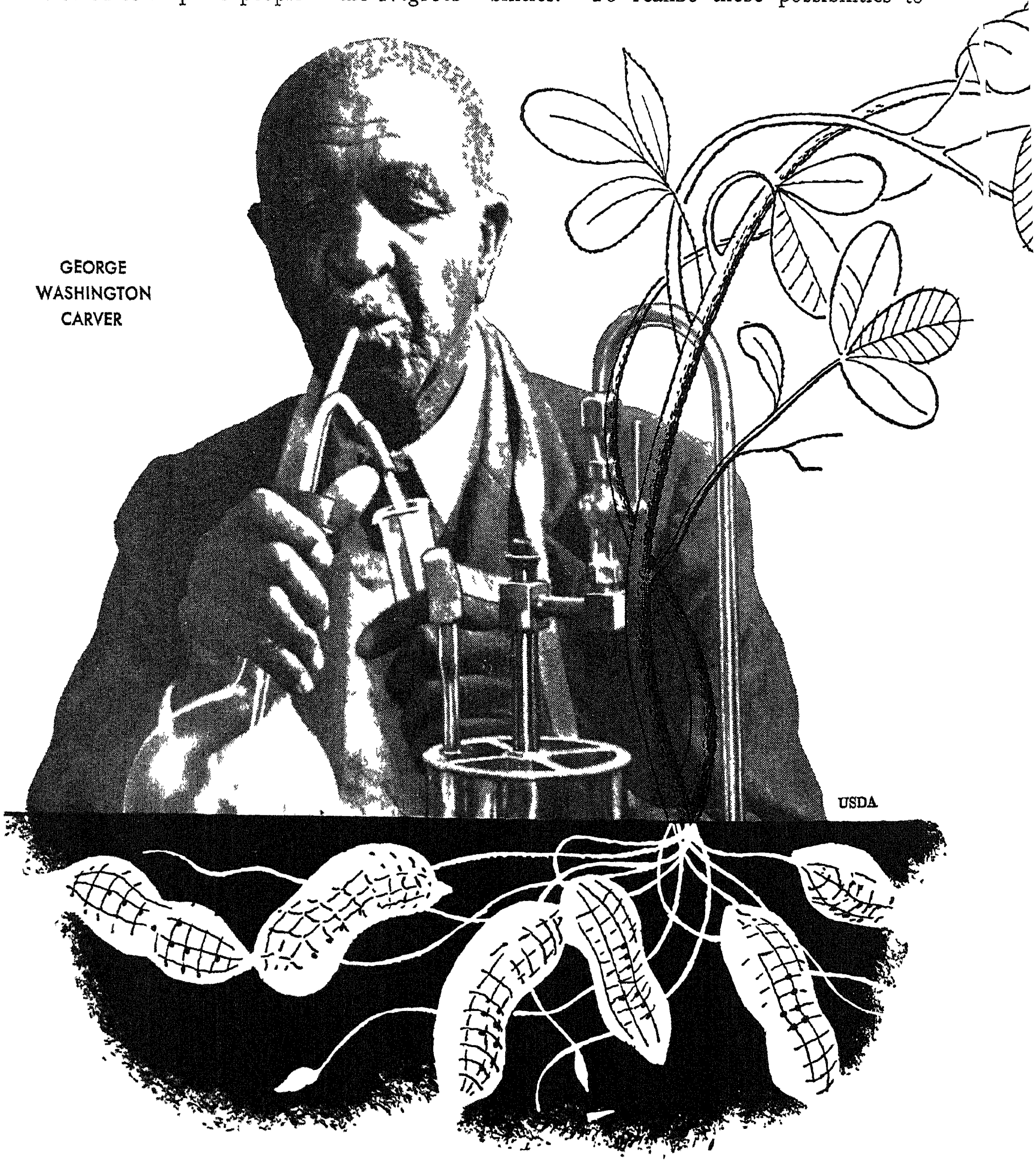
When he was about ten years old, George asked the master of the plantation to let him attend the one-room log schoolhouse at Neosho, Missouri, eight miles away. Carver told the lad that he was free to go but that he would have to shift for himself. The boy went off to Neosho without a penny in his pocket. He slept in barns, did odd jobs for his meals and eagerly devoured every bit of book learning that was available to him. A few years later, he worked his way with a mule train going sixty miles west to Fort Scott, Kansas, where he enrolled in the high school. Here, too, his life was a constant struggle with grinding poverty; he took in "white folks' washing" in order to pay his way. Then he went to Simpson College, in Indianola, Iowa. He attended this school for three years, supporting himself by doing odd jobs and running a laundry.

In the year 1890, when he was about twenty-six years old, he enrolled at Iowa

State College at Ames, and four years later he received the degree of Bachelor of Science in agriculture. In 1896 he obtained his master's degree. Meanwhile his wonderful skill with plants had attracted the admiring attention of his professors. He was given a regular job at the college; he took care of the greenhouse and did a certain amount of teaching.

The speeches and teachings of the famous Negro educator Booker T. Washington greatly influenced young Carver, who resolved to help his people — the Negroes of the South. In 1896 he accepted a teaching position at an Alabama Negro college — Tuskegee Institute — which at that time was a pitiful collection of shacks. His work at this school was destined to change the agriculture and much of the economy of the South.

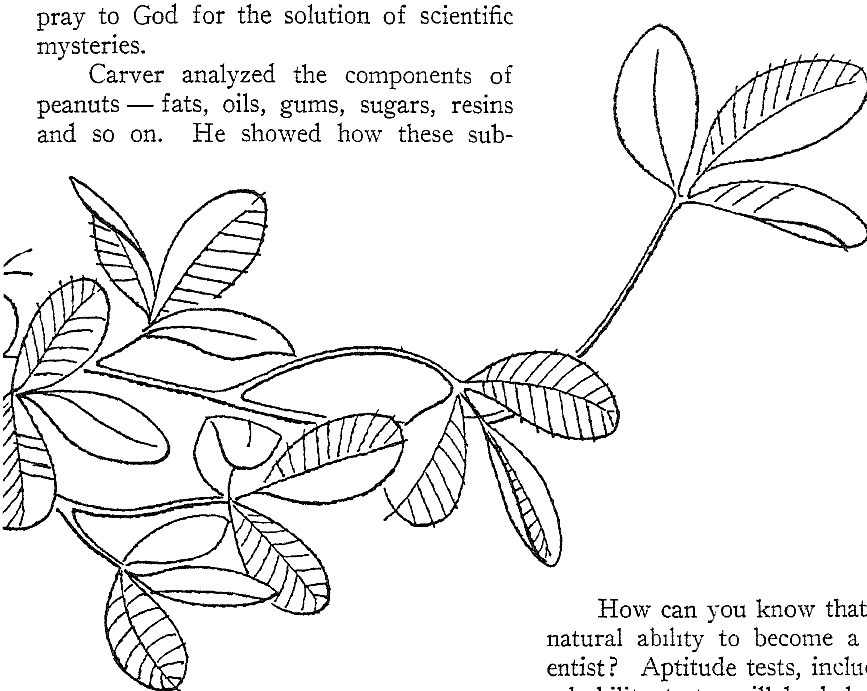
His first task was to introduce diversified agriculture to the cotton-impoverished soil of the South. He urged farmers to plant peanuts and sweet potatoes, which, he said, had tremendous industrial possibilities. To realize these possibilities to



GEORGE WASHINGTON CARVER

the full, he began a series of infinitely patient and persistent researches. He drew inspiration from early morning walks in the woods, where he would meditate and pray to God for the solution of scientific mysteries.

Carver analyzed the components of peanuts — fats, oils, gums, sugars, resins and so on. He showed how these sub-



stances could be chemically transformed into synthetic milk, butter and coffee and also into such varied products as flour, breakfast food, salad oil, shaving lotion, cosmetics, ink, wallboard and axle grease. He made 300 different substances from peanuts and 118 different products from sweet potatoes.

National and international honors came to this modest slave-born scientist — the "peanut man," as he was called. He received many fabulous bids from industry (including an offer of a $25,000-a-year job from Thomas A. Edison), but he refused them all. Living simply and piously, amusing himself with painting (with pigments that he made himself) and handicraft arts (he wove his own neckties), Carver had no need for vast sums of money. He was content in the knowledge that his work would help uncounted millions. He died in 1943. His story is an inspiration to young people seeking a career in science.

How can you know that you have the natural ability to become a first-rate scientist? Aptitude tests, including mechanical-ability tests, will be helpful; so will a heart-to-heart talk with a successful scientist or a science teacher. But, in the last analysis, only you can judge whether you have the qualities that characterize the genuine scientist. These qualities are:

(1) The capacity to work alone for hours, days and years, if need be.

(2) The willingness to shoulder responsibility.

(3) Courage — the ability to keep your head and to stick to your guns in a crisis.

(4) The ability to co-operate with other people — to understand the problems on which they are working.

(5) Curiosity — especially about the ways of man and nature.

(6) A liking for experiments and a feeling for accuracy.

(7) Independence — the willingness to map out your own path of investigation.

(8) A willingness not only to look after the details of your job but also to see it whole.

(9) A sense of deep personal satisfaction as you seek a scientific goal, despite lack of immediate glory, applause or financial reward.

(10) Imagination — the same quality that animates great writers, artists and musicians.

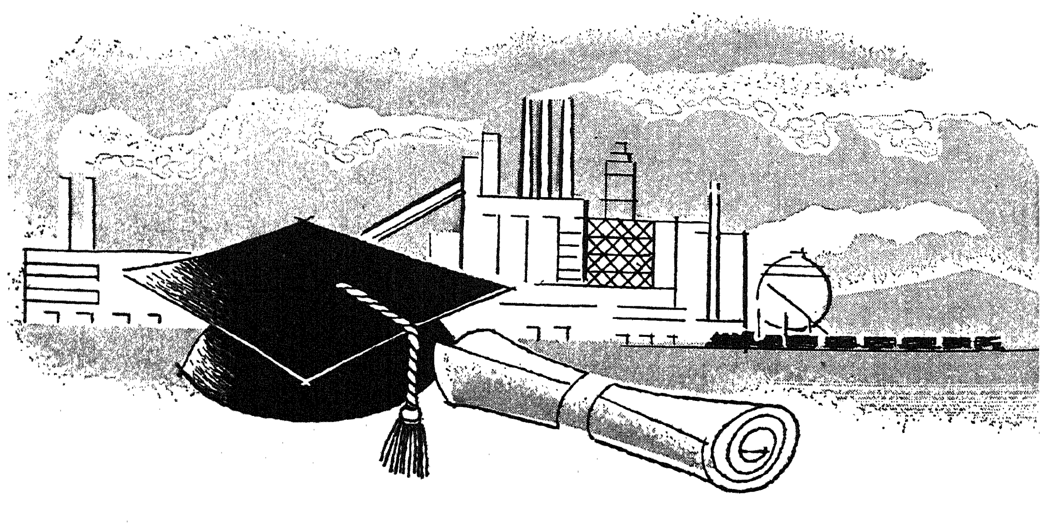
You cannot expect to possess in the highest degree all the qualities that are listed here. Certain great scientists have been strikingly deficient in one or more of them. Leeuwenhoek was content to peer eternally through his microscopes, caring little about general theories. Newton did not co-operate well with other people. Sir Humphry Davy was avid for personal glory, and this led him to be unjust to possible rivals. But, by and large, the qualities mentioned above describe the attitude of the genuine scientist.

Since science is built upon the combined wisdom of dead and living scientists, this wisdom must be sought out in books and museums as well as in the laboratory; in other words, a prospective scientist must acquire a thoroughgoing education. This education need not necessarily be entirely formal, but it must be effective. There may be self-taught scientists — though these have been few and far between — but there are no ignorant scientists.

Generally speaking, it is advisable to begin your scientific training in high school and to continue it in college and in a graduate school. The common sequence of degrees you will seek is B.S. (Bachelor of Science) or B.A. (Bachelor of Arts); M.S. (Master of Science); and Ph.D. (Doctor of Philosophy) or D.S. (Doctor of Science; also written Sc.D.). Usually four years of undergraduate work and three or more years of graduate work at an accredited college or university are necessary to obtain the Ph.D. and D.S. degrees. Other degrees are granted to scientists specializing in certain branches of science. For example, the degree of M.D. (Doctor of Medicine) is granted in medicine; the degree of D.D.S. (Doctor of Dental Surgery) in dentistry.

Your high-school training should include mathematics, at least one foreign language and several science courses, as well as English, history and other subjects. You will want to choose a college that has a good science department; the name "Institute of Technology" or "Scientific School" may be a clue. Or you may select a college on the strength of the teachers. For example, you may have been greatly influenced by a book written by a botany professor in a particular college; if you wish to major in botany, it might be a good idea to go to that college and to study with that professor. Incidentally, good science departments usually grow up around eminent scientists.

You may not be able to enter the college you have selected immediately. You can, however, usually make arrangements to go to a local college or junior college near your home and then transfer in the second or third year to the school of your choice. It is often easier to be admitted



to a particular college as a transfer student than as an incoming freshman.

Most universities have certain scholarship funds available to able students in all departments. You can find out about these funds by consulting university catalogues (often available in public libraries) or by writing to admission officers or deans. In both the United States and Canada, qualified veterans are provided by the government with funds to carry on college work. The amount of help given to each veteran depends on the length of his service, his family status and so on.

In the United States certain other scholarships are available on a limited scale. Most widely known, perhaps, are those offered through the organization known as Science Service, with headquarters in Washington, D. C. Science Service conducts an annual Science Talent Search on behalf of the Westinghouse Electrical Corporation. This contest is promoted through the Science Clubs of America. There are 10,000 or more of these clubs, many of them connected with high schools.

Do not specialize too narrowly at college. Your course of study should include literature, philosophy, art and other cultural subjects. If you neglect your general education, you may find it difficult to make up the lost ground later on.

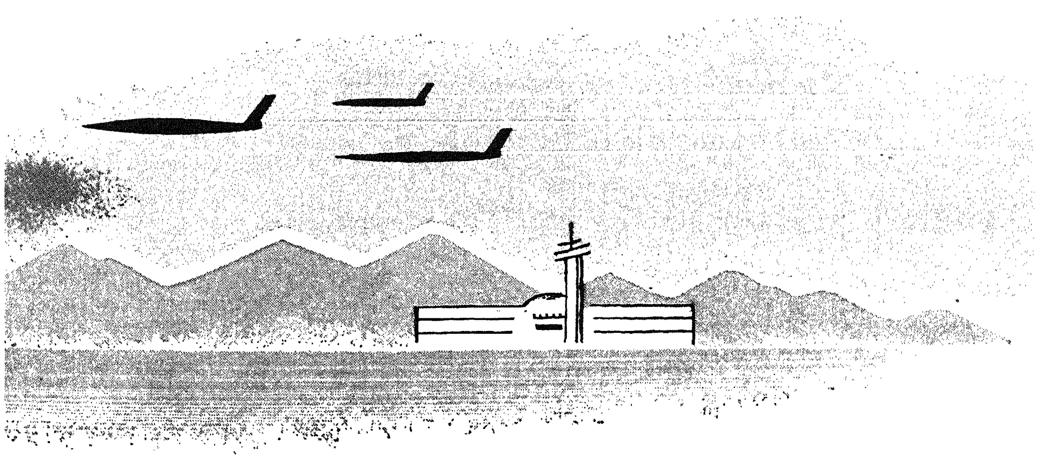
If you have had a satisfactory undergraduate record, you will generally find it easy to get into any graduate school of your choice. By this time you should have a pretty good idea of the field of science in which you will specialize. In seeking suitable subjects for your master's and doctor's theses, you will, of course, freely consult your professors.

As you acquire your basic training in science you may feel drawn to a career in pure scientific research. Or perhaps you may be particularly interested in some field of applied science — chemical engineering, electrical engineering and the like. Even if you later decide to transfer to a nonscientific activity, your scientific training will have developed in you qualities of observation, accuracy and method which will serve you well in any field.

CAREERS IN SCIENCE — A BIRD'S-EYE VIEW

When you have completed your scientific training, you will have to look for a job. Of course you will not ask a prospective employer for a job as a "scientist"; you will apply for a specific position in a specific field — as a junior chemist, or an instructor in mechanical drawing, or a medical-laboratory technician, or a petroleum geologist, or a forester or a research assistant.

It is important not to be misled by the label of this or that position. When you are seeking employment, ask for a *job analysis* or *job description* from your employer; it will explain what is expected of you. Do not turn down a job merely be-



Standard Oil Co. (N. J.)

Members of a high-school chemistry class working in the laboratory. High-school science teaching offers many fine opportunities.

cause it seems to involve too much petty detail. Every scientific position has research possibilities, no matter how humdrum it may seem. After you have shown your ability to carry out routine tasks, you will be given jobs that require greater initiative. In time, you may become a project director, with laboratory facilities and technical assistants working under you.

Sometimes a young scientist does not *find* a job — he *creates* a job through his special knowledge and skill. That is particularly true when a young scientist-in-training opens a new field of inquiry or devotes himself to some new development in applied science. For example, Lee De Forest created his own opportunities in the field of electronics because of his achievements as a pioneer in this field. That was also true of such electronic experts as Philo T. Farnsworth, Edwin H. Armstrong and Vladimir Zworykin. Not only did these men achieve success in their chosen field but they created positions for a great many other men.

What should you expect of a job in science? A leading personnel expert (a man whose task it is to keep other people happy and efficient in their work, so far as possible) maintains that, to be really satisfactory, a job should provide:

(1) An employer whom you respect, whose praise you treasure and whose criticism you accept because you realize that it is meant both for your good and the good of your job.

(2) Congenial associates with whom you get along well, whose teamwork and co-operation make your job more desirable.

(3) Reasonable security. In this respect university positions and civil-service jobs offer definite advantages over industrial jobs.

(4) Opportunities for advancement. Industry is particularly quick to reward initiative on the job.

(5) An adequate salary. Few scientists get rich, but they can usually look forward to enjoying a comfortable income.

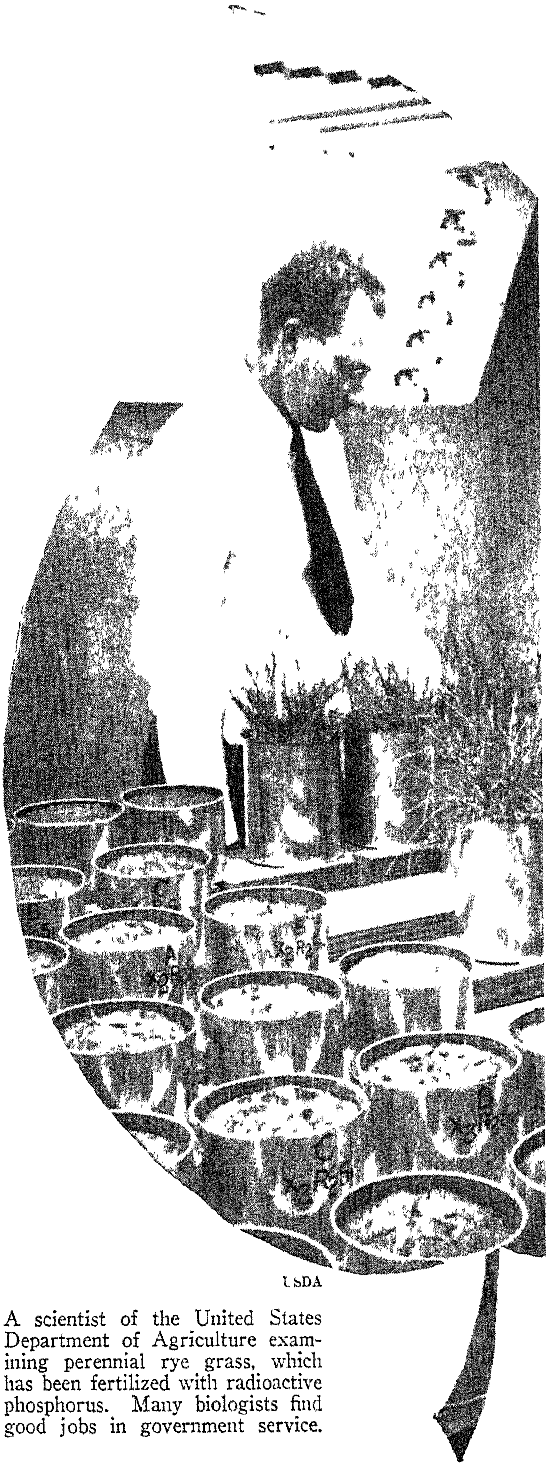
Positions for men and women with good scientific training fall into three major classifications: (1) teaching in high schools, colleges and universities, (2) positions in government agencies and (3) industrial research.

High-school teaching offers a richly satisfying career to those who like to work with young people. The opportunities in this field are increasing, since high-school curriculums are being constantly enlarged. To teach science in high school, one must have at least an A.B. from an accredited college and, preferably, an M.S ; certain courses in education are required in most cases. An increasing number of high-school teachers have gone forward with their graduate studies and have obtained their doctorates in science. Such teachers have a particularly good chance of becoming heads of science departments in their schools.

The Ph.D. or D.S. degree is practically a necessity for a successful career as a college or a university teacher of science. Occasionally a topnotch research man or technologist without a doctor's degree obtains an important teaching job, but this does not happen very often.

Steps in college teaching usually are assistant, instructor, assistant professor, associate professor, full professor, head of department. It usually takes ten to twenty years — or more — to become a full professor and to obtain a salary that may range from $5,000 to $15,000 a year. University science professors often add to their incomes by serving as consultants to industry or to government. A few particularly prominent professors, especially in the field of engineering, set up their own offices, and occasionally their own research laboratories, as independent consultants; they are paid regular retaining fees or special-project fees for their services.

When university teachers of science write for learned publications, they receive a certain number of reprints of their ar-



USDA

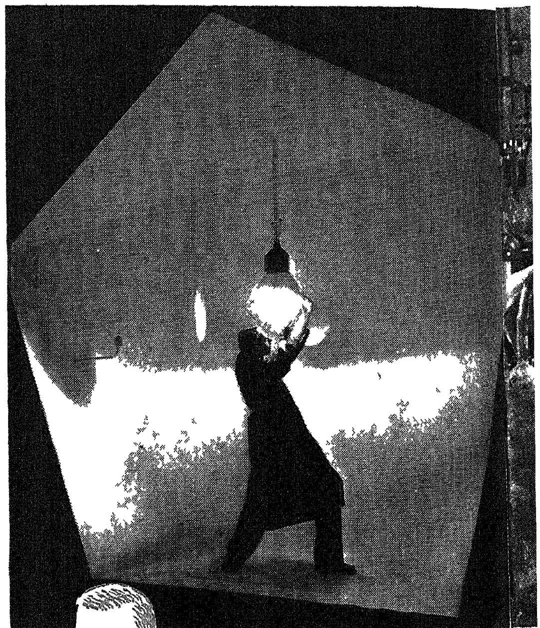
A scientist of the United States Department of Agriculture examining perennial rye grass, which has been fertilized with radioactive phosphorus. Many biologists find good jobs in government service.

ticles, but they are seldom paid for their contributions. On the other hand, they are paid, and sometimes quite handsomely, for articles in popular magazines and newspapers If they write science textbooks, they receive royalties, generally amounting to 10 per cent of the retail price. If a textbook is unusually successful, the royalties may represent a considerable amount.

Government service generally means employment under Civil Service in one of the numerous agencies of the Federal Government. Both the United States Civil Service Commission and the Civil Service of Canada announce competitive examinations for various science positions through posters displayed in post offices and elsewhere.

United States government service, in particular, offers opportunities galore to young scientists. The United States Department of Agriculture, for example, employs a great many persons trained in biological sciences. Many important scientific jobs are under the jurisdiction of the Army, Navy or Air Force. When scien-

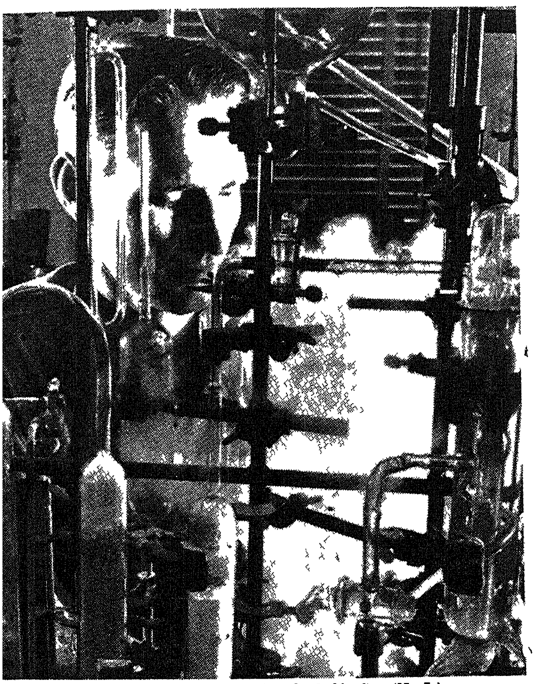
Industry offers a wide variety of positions for qualified men and women scientists. At the right, a lighting engineer, employed by a large American manufacturer of electrical equipment, is testing a big street light in a snow-white room with twenty sides.



Westinghouse

tists enter United States government service, they are given professional classifications by the Civil Service Commission. Salaries range from about $2,500 to $10,000, as one moves from P1 (Professional, first grade) to P6 (Professional, sixth grade) or P7 classifications. Government jobs provide generous leave provisions and steady salary increases.

There are a number of jobs in science in state (provincial, in Canada) governments and in such local governments as cities, school districts, sanitary districts



Standard Oil Co. (N. J.)

This laboratory technician is engaged in a soil analysis project in the well-equipped laboratory of an oil company.

and so on. Chemists, technologists, sanitary engineers and others find satisfying careers in such service.

Industry offers innumerable positions for qualified men and women scientists. Such persons generally find a place in an industrial research laboratory. In the United States, for example, there were only about 300 industrial research laboratories in 1920. Thirty years later, according to a bulletin of the National Research Council, there were 2,845 in all and they employed something like 100,000 people.

There are three kinds of industrial research laboratories:

(1) Plant laboratories. These analyze and control (often by statistical as well as by experimental methods) the materials, processes and products that are handled in a given factory.

(2) Development laboratories and "pilot plants." Here attention is directed to improvements in the company's product and to economies that will make it possible to lower the costs of production. Such improvements and economies have brought about mass production of radios, washing machines, automobiles, cellophane and so on.

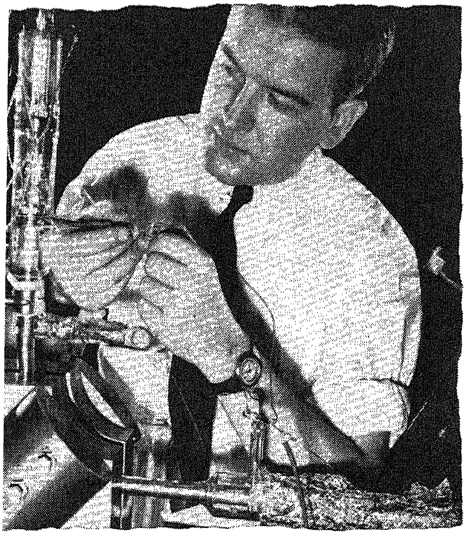
(3) Basic research laboratories These laboratories carry on research in fundamental sciences bearing on a given industry. Great industrial leaders have long recognized the need for such research George Eastman once said: "The future of photography is in the laboratory."

Salaries of scientists in industry generally start at $3,000 a year (or more) and may range up to $25,000. Of course, if a scientist becomes a partner in a large firm, the figure is much higher.

The labor market for scientists in industry fluctuates with the times. In depression days, for example, physicists had a rather lean time of it in the field of industry. After World War II broke out, there was a steady demand for young physicists, particularly for those with training in electronics and nucleonics (the science dealing with atomic energy).

Industry offers particularly rich rewards to skillful research scientists with marketable ideas. The main job of a research director in industrial laboratories is to keep his eye open for such scientists. If he can add a few really productive research workers to his staff, his reputation is established.

Most large industrial firms make a special canvass of colleges at the end of each year to seek out and hire the most likely men among the crop of new gradu-



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There are opportunities galore in the fields of nucleonics (the study of the phenomena of the atomic nucleus) and electronics (dealing with the emission and behavior of electrons, particularly in electron tubes, photoelectric cells and so on). In the large photograph at the left we see a million-volt atomic generator for research in nucleonics. The inset shows the operation of a "robot chemist," a form of mass spectrometer. This electronic device is used to analyze the chemical content of gases and vapors. Above is Dr. John A. Hipple, who developed the apparatus. The photograph at the bottom of Column 2 shows another electronic device — a cathode-ray oscillograph, which uses an electron beam to measure voltages.

ates. Your chances of being selected are improved if you can obtain a good letter of recommendation from a professor in your chosen field or if you are near the top of your class. Prospective employers are also bound to be impressed if you have completed a special research job or if you have had an article published in a recognized scientific journal.

There are more jobs in industry for chemists than for any other scientific group. The field of chemistry (and chemical engineering) offers opportunities in (1) agricultural and food chemistry, (2) biological chemistry, (3) cellulose chemistry (plastics and explosives), (4) dyes, (5) fertilizers, (6) gas and fuel (especially coal and petroleum), (7) industrial and engineering chemistry, (8) the leather and gelatin industries, (9) medicinal products (pharmacological chemistry), (10) metallurgical chemistry, (11) organic chemistry, (12) the paint and varnish industry, (13) photochemistry, (14) physical chemistry and inorganic chemistry, (15) rubber, (16) sugar, (17) water supply, sewage and sanitation and (18) nuclear chemistry.

There are also many jobs in industry for physicists. You may become a civil, mechanical or automotive engineer. You may get into aviation — as a power-plant designer, an aeronautical engineer or a meteorologist. Electrical engineering offers many opportunities; so does electronic research in such fields as radio, radar and television. Your research or development job may be in the fields of optics, lighting or acoustical engineering. As a mathematical physicist you may do research in nucleonics. You may be a transportation engineer, an instrument designer, a climatologist on a soil-conservation project, a

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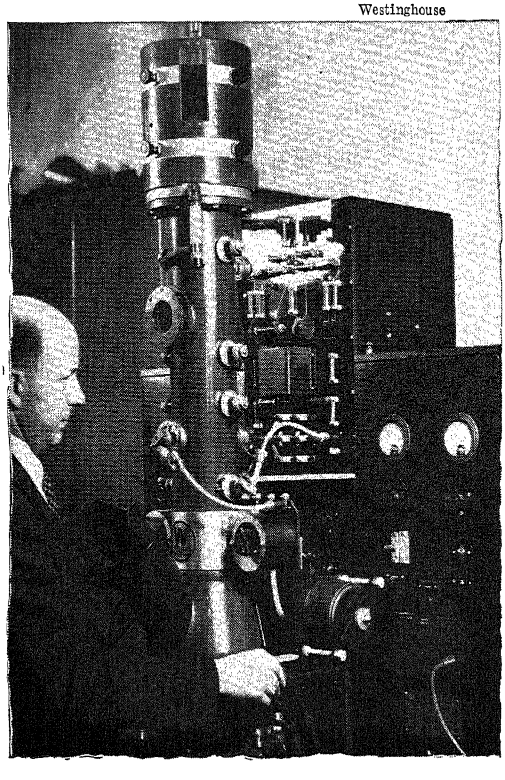
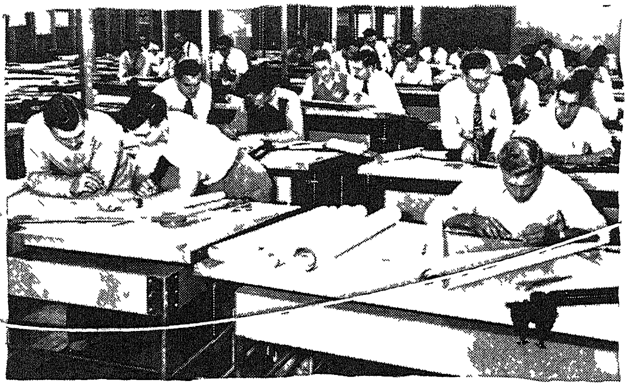


← British Info. Services; (inset) Gen. Elec. Co.



Glenn L. Martin Co.

Hundreds of men like those who are shown in the above photograph are employed to make the original design drawings of any new airplane. It generally takes years before the plane is ready for production on a mass basis.

specialist in glass manufacture, a mining engineer or a consultant in the manufacture of X-ray tubes.

Geologists are in great demand in industry, particularly to search for raw materials and to exploit them efficiently. This applies to the vast petroleum industry and to the industries based on coal, gold, copper, lead, uranium and so on. Geologists carry on prospecting activities; they often direct mining and drilling operations. They play an important part, too, in engineering projects. They locate the most convenient sources of building materials, such as rock for road construction and also the gravel and broken stone used in the preparation of concrete. They test foundations for railroad beds, bridges, dams and airfields and the possibilities for water supply and drainage.

Standard Oil Co (N. J.)

Geologists are in great demand in a number of different industries. The young geologist in the above illustration is operating a gravity meter, a delicate device that is used to study the nature of subsurface structures.

There are other careers in science besides those in teaching, in government work or in industry. Medicine and dentistry, for example, offer unparalleled opportunities for service to mankind as well as for financial success. There are many opportunities, too, in the writing field for persons who combine scientific knowledge with the ability to write clearly, interestingly and simply for the public at large We might note, perhaps, that some of those who have been most successful in this field have not devoted all their time to writing; they have also occupied positions as government biologists, directors of research departments, roving editors of magazines, professors of astronomy and what not.

People who devote their lives to science generally derive a vast amount of satisfaction from their jobs. Sometimes, indeed, research workers may be so engrossed in their particular project that they may lose all interest in the world at large. They would do well to heed the warning of Albert Einstein that the chief interest of the scientist should be concern for man himself and his fate. "The creations of our mind," said he, "should be a blessing and not a curse to mankind. Never forget that in the midst of your diagrams and equations!"

SCIENCE THROUGH THE AGES is continued on page 4111.

A STAR'S LIFE HISTORY

Inferences as to the Development and Decline of Stars Made from Their Differing Appearances

THE MESSAGES BROUGHT TO US BY LIGHT

TO the unaided eye the stars differ in brilliancy and to a certain extent in color, but they appear on the whole to be very similar to one another. The spectroscope, however, shows that they differ very greatly in constitution, and may be classified into several definite kinds. Thus, we speak of solar stars, of Sirian stars, of helium stars and of yet other groups which we shall proceed to describe. It must be remembered throughout, however, that these different kinds or classes of stars shade into one another, and that they very probably represent different stages through which individual stars pass in the course of their life history.

From the moment when the Copernican theory of the universe was generally accepted, the enormous distance at which the stars are situated from us became evident and undeniable Throughout the whole of the vast journey of our earth's orbit they appear immovable, except in rare cases and to the finest measurements astronomy has yet attained. This immobility implies that they are at such a distance from us that the length of our orbit, from one end to the other, is as nothing in comparison. It is also obvious, therefore, that the light-giving power of these bodies must be immense, or none of them would be visible to us across these immeasurable distances. So it becomes certain that the stars are of the nature of suns, of enormous size and brilliancy.

Nothing, however, of the physical constitution of stars can be learned from telescopic observations. Even the most powerful modern telescopes cannot succeed in magnifying the star images to any perceptible dimensions; they remain, and will remain to the end, mere points of light as far as direct telescopic vision is concerned. But indirect methods enable us to measure the diameter of some of the stars and the application of spectroscopic analysis has made it possible to decipher in some degree their physical nature, and hence much which was formerly conjecture is now certainty.

The application of this analysis to a general survey of the heavens was first successfully carried out through the unremitting labors of Father Angelo Secchi, the noted Jesuit astronomer of the Collegio Romano, who died in Rome in the year 1878. His investigation of the spectra of over 4000 stars, made during 1862 and the following years, enabled him to classify the stars under four main spectral types which still form the basis of the more detailed modern classifications. A far more extensive survey, including about a quarter of a million stars, and constituting a truly monumental work, has been carried out with the aid of photography by the Harvard College Observatory under the direction of the late Professor Edward C. Pickering and his collaborators, especially Miss Antonia Maury and Miss Annie J. Cannon. The main results of this survey are included in the famous Henry Draper Catalogue and other publications of the Observatory.

The possibility and success of this method of analysis depend on the fact that the stars are suns, enveloped like our own sun with photospheres, or mantles of incandescent vapors, shining with enormous brilliancy. Some of them, gener-

ally classified apart as solar stars, give a spectrum almost exactly identical with that of our sun, and are, therefore, so far as can be ascertained, bodies of precisely similar character. It seems astounding that so much can be known from the mere analysis of the light which we receive from the stars, for this light is in no case more than a tiny shaft or pencil. But that single pencil of light is collected from the whole hemisphere of the star, and in its very constitution — as true in this tiny thread as in the broadest beams — brings to us, stamped in characters of light, undeniable indications of the chemical constitution and physical state of the body from which it comes.

What spectroscopic analysis has revealed of the physical nature of the stars

The spectra of the stars reveal to us a vast range of these sun-like bodies, sweeping in practically unbroken gradations from suns of a size and splendor many times exceeding those of our own luminary through the ordered harmonies of greater and lesser lights down to bodies which connect the stars with nebulæ, and, not impossibly, even with comets.

This sun-like quality, consisting in the presence of a radiating photosphere which constitutes a vast fountain of light, is recognized in a spectrum which is *primarily* unbroken. That is to say, the spectrum consists, not of bright lines or bands here and there, but of a ribbon passing through the whole range of colors from the red to the violet. The dark lines and bands which are marked upon the background of this continuous spectrum allow us, on the other hand, to distinguish various classes of stars definitely one from another, according to the physical conditions of the star itself, which we are able to learn, in some degree, from this chart. The continuous spectrum shows at once that we have to do with a sun-like body; the dark lines show what kind of sun-like body is before us. For the continuous spectrum comes from the photosphere of the star, and the dark lines and bands are due to the atmosphere which surrounds that photosphere.

Stars that seem to have the same composition as our sun

Typical solar stars, which form a large proportion, not very far from one-half, of all the stars that have so far come under observation, give a spectrum in every respect similar to that of our sun The continuous spectrum of the photosphere is crossed by innumerable fine dark lines, due to the absorption of light of definite wave lengths by various gases and metallic vapors in the cooler atmosphere above. The traces of hydrogen are slight in this class of stars, there being only four hydrogen lines which are visible in stars of true solar type.

Where, however, as is sometimes the case, more than four hydrogen lines are present, it may not improbably turn out that the reason is to be found in the existence of a companion star — that is to say that the spectrum is really that of a double star. This has recently been proved to be the case in Capella, for long regarded as a model solar star, but in whose spectrum extra hydrogen lines appeared in the violet. These lines are now known to belong to a companion of the Sirian type. In solar stars, as in the sun itself, the lines of calcium are very marked; they are two broad lines in the blue and violet, very prominent in the solar spectrum.

The enormous differences in size between the sun-like stars

It is practically certain that the constitution of these solar stars is identical with that of the sun, and that they would reveal, if closer examination were possible, a similar array of magnificent appendages, such as sunspots, faculæ, prominences and corona. Stars of this type vary enormously in size. Canopus, perhaps the largest, being estimated as nearly six million times the volume of our sun, while one of the most insignificant, a star in the constellation of the Great Bear known as "Groombridge 1618", is of such small dimensions that it would take three hundred and fifty of like size to make up the sun; yet both are true solar bodies, and between them are others of all sizes.

This wide difference in size means a wide difference also in the value of the force of gravity at their surfaces; yet the identity of their spectra seems to prove that not only are the proportions of chemical elements the same in all, but also the conditions of temperature and of pressure must be the same, though these conditions are, of course, considerably affected by gravity. The explanation probably is that there is a constant ratio of forces in these bodies; and the late Miss Agnes Clerke suggested that "we might even venture tentatively to define solar stars as bodies in which the ratio is the same between gravity and electrical repulsion".

One of the most remarkable features of stars of this class is that they remain in very large numbers unalterably true to type, their spectra showing so closely alike that they can hardly be distinguished. This seems to indicate a particularly permanent condition of existence, and may perhaps be taken to imply a long life, without any very considerable change, for our own sun.

Sirian stars that shine dazzlingly through an atmosphere of hydrogen

These solar stars are generally of a somewhat golden tinge. The enveloping vapors that intercept much of the photospheric light in bodies like our sun produce a mellowing and softening of its quality, otherwise it would come to us in a dazzling blue brilliancy. Such is, in fact, the nature of the light we receive from another class of stars, more numerous even than the solar stars, and probably comprising one-half or more of all that are known.

These are the Sirian stars, named after Sirius, the Dog Star, which is the most famous example of their type. They are of a radiant white or blue color, and show a spectrum remarkably free from dark lines such as are found in immense numbers throughout the length of the solar spectrum, and are due to metallic absorption. The lines of hydrogen, however, which are but faintly marked in the spectrum of the sun, are peculiarly dark, broad and complete, the whole series being present in every typical star of this class.

This signifies that Sirian stars are surrounded by an atmosphere consisting principally of hydrogen. Their brilliancy in proportion to their estimated mass, in the few cases where such estimate has been possible, is remarkable. Sirius presents peculiar advantages for the purpose of such comparisons. It has been more closely observed than almost any other star, and it is also one of those nearest to our earth. It is at a distance from us which it would take light somewhat less than nine years to travel. This is a very short distance compared with the hundreds and thousands of light-years at which many stars are placed from us. Sirius has a faint companion, and it has been possible to find the character of their mutual revolutions, and from these, combined with the parallax, to compute the mass of the bright star of the Sirian pair. This is found to be two and a half times the mass of the sun, so that it might be expected to give a light not quite twice as great The actual brilliancy of Sirius, however, is forty-eight times that of the sun — that is to say, the ratio of light to mass is in Sirius about twenty-one times greater than it is in the sun.

The reason of the superior brilliancy of Sirius as compared with our sun

The spectroscopic analysis of their light affords us the means of accounting with considerable probability for some part, at least, of this luminous superiority in Sirian stars. The Sirian spectrum is, as we have seen, peculiarly deficient in dark lines showing metallic absorption, which implies that these stars are not surrounded by an envelope of metallic vapors, such as encircles the sun and absorbs a large proportion of the light from the photosphere. They are surrounded, on the contrary, by an envelope consisting almost exclusively of hydrogen, and therefore more transparent. It seems certain that a very large proportion of the light produced by Sirius is radiated directly through space, and that we receive its brilliancy nearly undimmed. In the case of the sun something like one-third of the original light is lost to us by self-absorption.

There are also other contributory reasons for the excess of luminosity. For example, it is known that Sirius and stars of the same order are of a density much less than that of the sun, so that they have photospheres much larger in proportion to their mass. The exact ratio of the radiating surface can, in most cases, be only roughly estimated, but the absence of any considerable loss of light through absorption by enveloping vapors in the Sirian star is an established fact recorded with undeniable clearness in the spectrum.

Intermediate grading of stars between type and type

Between the two definite types of Sirian and solar stars is an uninterrupted series of gradation-types combining in different proportions the characteristics of the two. Thus, as the hydrogen lines, dark, broad and complete in the Sirian stars, become fainter and thinner, and as the series becomes less completely marked, the numerous delicate rulings of the solar spectrum begin to appear and assume gradually more and more predominance until we get the true solar type. In some intermediate examples the characteristics of both appear clearly marked and quite evenly balanced, so that it is a difficult matter to classify these stars. In 1896 Schaeberle discovered, at the Lick Observatory, the faint companion of Procyon, thus establishing its binary character, but the light giving the spectral lines probably comes almost entirely from the brighter of the two stars which is thought to combine in itself the features of the two types in remarkable equipoise and completeness.

The helium stars emerging out of nebular surroundings

Within the last twenty years a special set of stars, which had been usually classed among the Sirians, emerged into importance as a class apart, representing a stage still further removed from solar stars than are the ordinary Sirian or hydrogen stars. These stars show, of course, like all others, the continuous spectrum, but it bears in this case almost no markings upon it. The spectrum is almost blank. But the hydrogen lines can be just made out, and, what is of chief importance, and gives their name to this group of stars, there are well-marked signs of helium. These helium lines disappear from the spectrum of true Sirian stars, and the dark, bold hydrogen lines are predominant instead.

Helium stars are of great interest and importance, for they have been found to have close analogies with gaseous nebulæ, and in some cases they appear to have nebulous appendages attached to them. Among the stars with strong helium lines a small number, known as Wolf-Rayet stars, show striking spectral similarity to planetary nebulæ, their spectra contain many bright lines but are also crossed by a large number of dark lines which are altogether absent in the typical helium stars. These dark lines are certainly not the metallic absorption lines found in the spectra of solar stars and their origin is still unknown. The Wolf-Rayet stars, numbering about a hundred, and the helium stars which are much more numerous, are found almost exclusively in the region of the Milky Way. The constellation of Orion is especially rich in helium stars, so much so that they are sometimes called Orion stars. They have been proved to be of very low density, and their light comes to us from the photosphere with even less loss by absorption than that of Sirian stars. Practically all the light which is produced is radiated into space, and these stars are consequently all pure white in color.

The great helium stars that twinkle at us out of Orion

Bellatrix, in Orion, is a good example of a helium star. It has the bluish-white tinge significant of light which has suffered no substantial alteration from the action of intervening vapors; all portions of its light have the intensity proper to them. Rigel, a first-magnitude star at the foot of Orion, is a helium star in which other lines clearly show; the hydrogen lines are strongly developed in this star, though not of the same width and intensity of these lines in typical Sirian stars. When

hydrogen attains the predominance which it has in Sirian stars, helium is no longer to be perceived; it can apparently hardly imprint itself except when practically in sole possession of the field.

Why some stars shine with a clearer light than others

The light of Sirian stars, and still more of helium stars. comes to us, then, very much more directly than solar light and in much greater native purity. It is more violet in tone and of an intense flashing brilliancy. These stars seem to be at a very high temperature and considerable difficulty has been found in accounting for the absence of the metallic vapors in their surrounding atmospheres, for it is surely probable that increased heat would intensify the process of metallic vaporization, and so produce a more complex enveloping atmosphere, and thus increase the absorption of light. It is thought by many that the absence of metallic vapors is due to the greater effective force of gravity in Sirian than in solar stars. But a more satisfactory solution of this question will probably be obtained before long by the application of the theory of ionization recently developed by Dr. Saha, of the University of Calcutta, and elaborated by Milne, Russell and others. This theory relates especially to masses of gas or vapor at high temperature and reduced pressure, conditions characteristic of the solar and stellar envelopes: it is a very fruitful theory and has already enabled astronomers to account for certain hitherto unexplained differences between the ordinary dark-line spectrum of the sun and the bright-line flash spectrum of the solar envelope obtained at times of total eclipse.

The different effects of the absorbent power of vapors

Certain stars, usually classed as belonging to the solar type, because they conform on the whole to the spectrum of our sun, show, however, in some degree the characteristics of a very interesting class, varying from our sun in the direction contrary to that in which the Sirian stars vary from it. They bear signs of a greatly *increased* absorbent envelope of vapors, the spectrum showing almost complete absorption of the more refrangible or violet rays, while throughout there is a deepening of the lines which indicate metallic absorption. Aldebaran, the chief star in the constellation Taurus, is the most striking example of this transition stage. It is of a decidedly red color, and of tremendous light-power. In spite of the amount of self-absorption which its light suffers, it is of the first magnitude, and its brightness is estimated at not less than twenty-eight times that of the sun, and probably more. Its spectrum shows the lines of metals with high vapor-densities, which are absent, or nearly so, from the spectrum of the sun. It is clear that the enveloping vapors of this star are not only more extensive, but are also of a more complex and more absorbent kind. The violet rays hardly succeed in getting through at all, and it was only with the utmost difficulty that any impression of them has ever been obtained. More significant, and significant in the same direction, are the traces of incipient "flutings" in the spectrum of this star, for they connect it with the following classes.

A small proportion of the stars so far observed show clearly in their spectra the bands described as flutings. They are of two distinct kinds, separating the stars in whose spectra they appear into two sharply-divided classes, with none of those gradations between them which usually diffuse the boundaries of marked physical differences. In the first case, the bands are sharply defined towards the violet end, but shade off gradually towards the red. They occupy identical positions in all members of this class; the type is so far absolutely fixed. The stars vary, however, in the intensity with which they show the bands, and also in the relative importance of the bands in the spectrum. This band-spectrum is, as it were, superimposed upon a spectrum of the solar type; it represents, therefore, a stoppage of light which takes place at a further distance from the photosphere and consequently in gases of a lower temperature.

The progress of knowledge respecting the chemical meanings of starlight

It is thought that these bands are produced by chemical compounds as distinguished from chemical elements Yet no satisfactory explanation of them could for long be suggested The bands registered, in fact, a new kind of light-stoppage. It was seen that the bands themselves are made up of a great number of individual lines arranged in rhythmical series corresponding to the known series of the hydrogen lines, but pressed closely together; each band represents, so to speak, a condensed but rhythmical series of lines. In 1904, a beginning was made in penetrating the chemical meaning of these bands when it occurred to Professor A. Fowler to compare the flutings of these stars, which are often called Antarian, after Antares — the chief star of the constellation of the Scorpion and a first magnitude star of this class — with those produced by titanium oxide when rendered luminous by the application of electricity at low tension. The result was a great discovery. The flutings of titanium oxide agreed with remarkable closeness with eight out of the ten bands of the Antarian spectrum; and this agreement was found to extend to the arrangement of the lines which make up the flutings. A great step forward was thus achieved, and the predominant rôle of titanium oxide in producing the Antarian flutings established.

The great red Antarian stars with their signs of titanium oxide

These stars are all of a red or reddish color, and many of them are what are called "variables" — that is to say, they are subject to fluctuations in brilliancy ranging in some cases over several magnitudes.

A beautiful star of this class is Betelgeux, the brightest star of Orion. Its banded spectrum is clear, but faint enough to allow the line spectrum below to be distinctly seen. Betelgeux is of a deep red color, and, in spite of the amount of light lost by absorption, is of the first magnitude. In the brightest star of the constellation Hercules, the intensity of the bands has deepened so considerably that the intervening parts of the spectrum are thrown into vivid contrast, and appear as bands of brilliant light — so powerful, indeed, that some observers have concluded that bright lines are present in the spectra of this and similar stars; this, however, is very unlikely, though it may be the case.

Stars that vary their light through the thinning of their atmospheric vapors

All stars so far known which have banded spectra are at a very great distance from us, and are of extreme immobility. Yet we find among them stars which, even at inconceivably enormous distance, and after suffering very great loss of light by absorption, still come to us with a brilliance of the first magnitude. Their total luminosity must therefore be extraordinarily immense. Betelgeux is so far away that its light takes over 180 years to reach us, but its size makes up for its distance, and the recent measurements of its diameter secured at Mt. Wilson by means of Michelson's interferometer method show that its photosphere is about 75,000 times larger than the sun's photosphere and its volume about 20,000,000 times the sun's volume. Antares is almost twice as far away and yet gives us as much light as Betelgeux, its diameter being 500 times, and its photosphere 250,000 times greater than the sun's.

Another wonderfully beautiful star of this class is Omicron Ceti, called Mira (the "wonderful"), a variable star of a glowing red color, in which, however, the radiating function is already considerably decreased, and the absorption by surrounding vapors is very great, as reflected in the deep shading of the bands in its spectrum. It has been discovered that the fluctuations in brightness are caused by the movements of the surrounding layers of light-stopping atmosphere, which at one time close in thickly and at another thin off. When the star reaches its most brilliant phase, several substances, but in a supreme degree hydrogen, are kindled into vivid rays, in a manner suggesting the action of magnetism.

Stars that are farthest removed from the sun in their composition

About 15 per cent of Antarian stars are known to be variables, and most of the remainder appear to show symptoms of some degree of instability. The more variable the star, the further it would seem, according to its spectrum, to be removed, in constitution, from the sun. Many hundred stars of this type are known up to the present. They lie more or less isolated, and do not collect into groups.

The other type of stars with banded spectra, called "carbon stars", are, however, found for the most part grouped together in special localities in the heavens, particularly in the Milky Way. The bands in the spectra of carbon stars are shaded in the reverse direction from those of Antarian stars — that is to say, they are sharply defined towards the red and shade off towards the violet. There are three principal bands of the carbon type to which great interest attaches, owing to the fact that they are found to lie in exactly the position of the three *light* bands which have been looked for, so far in vain, in the spectra of comets.

Carbon stars beyond the reach of natural human sight

There is no doubt that these bands are due to carbon, and, it is conjectured, to carbon in some form of combination with hydrogen, for the same absence of hydrogen lines has marked their spectra as has marked the spectra of comets. It is believed that the only way of accounting for the lack of any sign of this most universal of substances is to consider that it is all used up in the formation of hydrocarbons Additional weight is lent to this theory by the fact that these three bands are exactly in the position of the three bright bands produced by burning alcohol and other hydrocarbon substances Traces of cyanogen have also been discovered in spectra of carbon stars. The only other elements so far identified are sodium and iron, and it is interesting that these two metals, and no others, have once or twice been traced in the spectra of comets.

The important discovery has recently been made that *bright* lines in large numbers are interspersed among the dark lines of some of these star spectra.

In these bright lines — which are always due to the shining and not to the absorptive power of gases — we seem to trace affinities between carbon stars and gaseous stars and nebulæ. The dark lines of their spectra, however, seem to show that they are more nearly related to solar than to Sirian stars, for their dark-line spectrum is very like the solar spectrum. Another sign of this relationship may be found in the fact that their light is blurred and fitful, and of a red color, all of which conditions point to a further development of the vapors which surround solar stars. The carbon stars are less numerous than those of the other types just considered and all except a few of them are visible only by the telescope.

Does the appearance of the stars tell the story of their development?

They are at unimaginably great distances from the earth, but the faintness of their light is chiefly due to the enormously thick curtain of vapors in which they are enveloped, so that it is only when this curtain is rent or attenuated that rays of light can succeed in making their way through in any considerable strength. The violet rays, being most refrangible, are cut off entirely, or, if they get through at all, are exceedingly faint. The color of the light is therefore usually deeply red. But it now appears that there are some exceptions to this rule, for two stars have been discovered giving spectra of this class, but continued well into the blue, and themselves white in color. Carbon stars are sharply distinguished from the first-named class of stars with banded spectra — *i.e.*, the Antarian stars. No combination of the two kinds of spectra is ever found; there are no gradation-types between them.

It is generally believed by astronomers that in the gradually merging types we have exhibited the successive stages of a star's development. The completeness of the progressive series and the unmistakable

affinities between them naturally suggest such a view. A number of facts, however, seem against it; among such facts may be specially mentioned the tendency by which the stars group themselves in space according to their kind. Certain kinds are practically restricted to certain portions of the sky. The significance of this is not, however, by any means clear and only by long-continued research may we hope to arrive at its meaning.

Conjectured cycle of stellar life through helium, Sirian and solar periods

The facts that helium stars are in some cases not detached from nebulæ, and that they are of very low density, were at one time taken as direct evidence of comparatively recent emergence from the nebulous state; and it was thought that they must be the youngest of the stars. That once assumed, the succession through Sirian and solar types is unbroken, so that no definite boundary line can be drawn where helium stars end and Sirian stars begin, or where Sirian stars end and solar stars begin. Many astronomers see in this a strong presumption that our sun, starting from the nebulous state has progressed from the nebulous state, to that in which we know it, by passing through all the stages represented respectively by these types of stars, and by all the gradations between them. The classes of stars we have been considering would, then, according to this view, represent the progressive development of a star's existence somewhat as follows.

In the earlier stages of its condensation from the nebulous matrix, the star is practically free from surrounding atmosphere, and is of very low density. Its light-producing surface is very large in proportion to its mass, and the light itself reaches outer space without any sensible modification, and preserving the blue tinge proper to photospheric light.

The rise and fall of the temperature of suns through unnumbered years

With the gradual wasting of heat by radiation, gravity gains a relatively greater influence and the body slowly contracts.

Although there is this continual wasting of heat, there is for a very long time no loss of temperature; indeed, there is a constant rise of temperature. This is because condensation renews the supply of internal heat more quickly than radiation reduces it, the kinetic energy of the particles falling towards the center being transformed into heat when this motion is arrested. Thus, the process of condensation may go on for ages attended by a rising temperature, until it reaches a maximum; it is only then that the constant giving out of heat begins to tell upon the body itself, and it cools slowly down to extinction.

The doubts and questions that arise in our conjectured life history of a star

This conjectured course of a star's life, however, presents many questions and raises many doubts difficult of solution. The law of increase of temperature in a contracting gaseous mass would seem to show that the order of development is from the dull hued Antarian stars up to the brilliant helium stars rather than in the reverse direction. Another difficulty against the theory arises from the fact that though condensation actually increases, as a rule, in due order through helium, Sirian and solar type stars, with increasing modification of their light apparently due to thickening vapors surrounding them, yet the Antarian stars, the last in the theoretical series, are generally much less dense than the stars of preceding type, and appear to be very much more nearly related to nebulæ than are the helium stars or Sirian stars or solar stars.

These and other considerations have helped to bring into increasing favor the theory set forth by Sir Norman Lockyer and later on developed, with certain notable modifications, by Professor H. N. Russell, of Princeton University, who was awarded, in 1921, the Gold Medal of the Royal Astronomical Society for his contributions to the study of stellar evolution. According to this theory, nebulæ condense first into tenuous Antarian stars of relatively low temperature and shining with dull red light, but yet of very great luminosity

on account of their enormous size; by virtue of the force of gravitation these stars, which are still entirely gaseous, continue to contract with a resulting rise in temperature and increase in the brilliancy of their light, and pass through the solar, Sirian and helium types, in which last stage they are hottest and shine with the purest white or bluish light and present the simplest of all stellar spectra. It is supposed that at this period of their history the density has become considerable and consequently the stars begin to lose the thermal properties of a truly gaseous body; when this takes place the heat due to further contraction is less than the quantity radiated into space and hence the temperature of the stars begins to fall whilst at the same time the radiating surface becomes smaller and the stars retrace their way from the helium type through the Sirian, solar and Antarian types on down to final extinction. Great stress is laid in this theory on the distinction between giant stars and dwarf stars, the giant stars of any type being on the ascending line of stellar life and activity and the dwarf stars of the same type being on the descending line. Our own sun is a dwarf star and of exceptional density, only a very few stars of known density, such as W Ursæ Majoris and Jordan's eclipsing variable, being more dense.

If the above theory is a correct presentation of the facts of nature, it follows that our own luminary is very old, and nearing the end of its active life. But yet it would be rather rash to draw any apodictic conclusions from these theories: and though it may prick our pride, it is well not to forget the caution advised even by ardent advocates of such theories, which after all are inferences based on observational data that, in comparison with the vastness and the complexity of the processes involved, are slender indeed. In his "Introduction to Astronomy", Professor F. R. Moulton, of the University of Chicago, enumerates some of the many assumptions, most of them tacit, which underlie every theory of stellar evolution, and after briefly indicating the tremendous difficulties that confront the astronomer in this region of his study, concludes thus: "Any theories of stellar evolution that may be developed at the present time are probably no more than first approximations, and they may be entirely wrong."

Recent developments in quantum theory and astrophysics have provided evidence showing that stellar energy is derived from the transmutation of elements. Protons, under the high temperatures prevailing in stars' interiors, move with great speeds and bombard the atoms, thereby liberating atomic energy.

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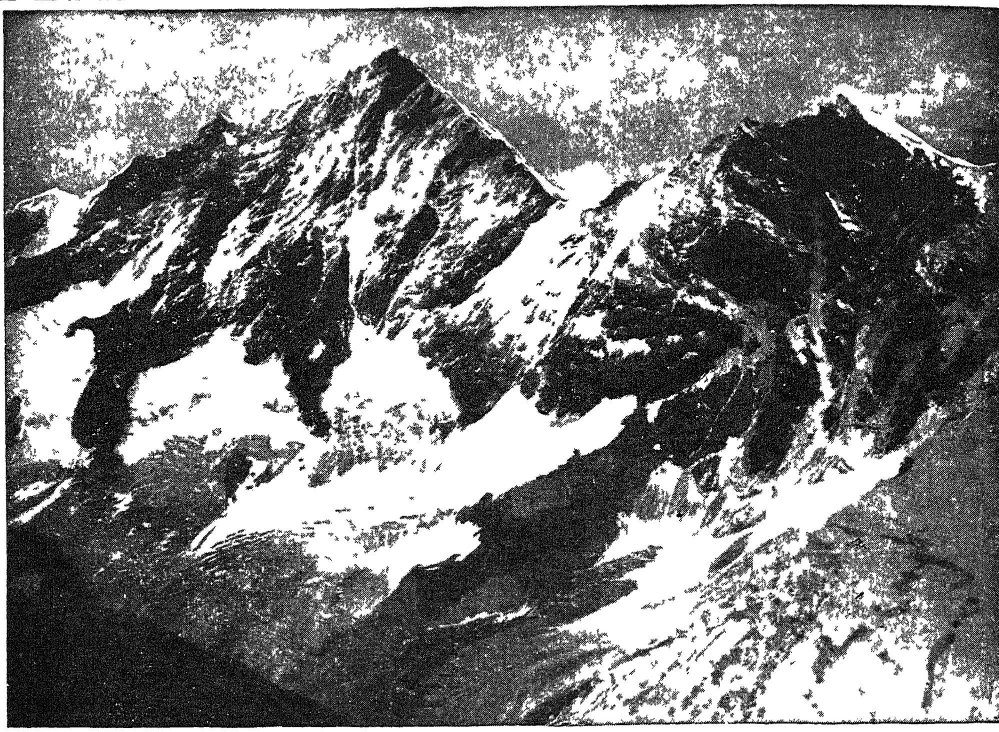
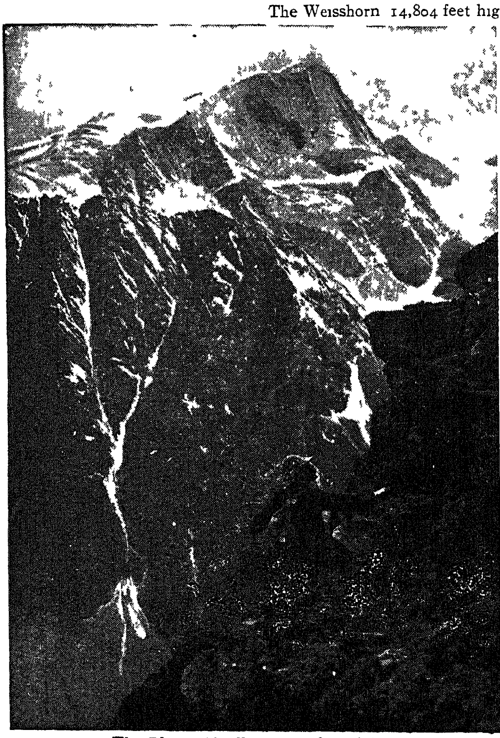
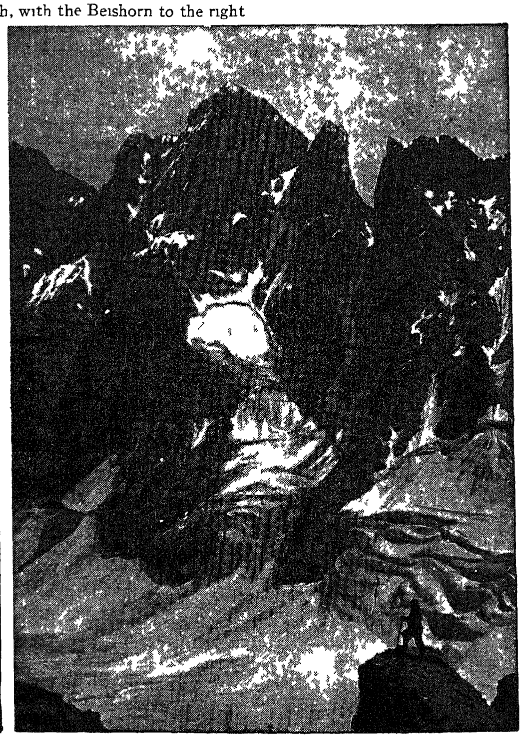
DEFIANT CLIFFS LONG UNSUBDUED



The Weisshorn 14,804 feet high, with the Beishorn to the right



The Pigne d'Arolla, 12,470 feet high.



Mount Pelvoux, 12,976 feet high.

SOME TYPICAL EXAMPLES OF ALPINE MOUNTAINS WITH EXCEPTIONALLY STEEP GRADIENTS

Photographs by Donald McLeish

THE MAKING OF MOUNTAINS

Some of their Features —Their Age, Their Steepness and How Fast they are Made and Unmade

CYCLES OF DECAY AND CONSTRUCTION

FOR the ordinary observer mountains are the symbols of immensity and immutability, and yet they are mere wrinkles on the face of the earth, wrinkles that are carved and smoothed by the eroding forces of air and running water

On a globe a hundred feet in diameter, modeled to scale, Mont Blanc would be represented by an eminence less than half an inch, and Mount Everest by one less than an inch high while on an ordinary school globe, two feet in diameter, "all the inequalities of the land surface would have to be sculptured in the thickness of an ordinary playing-card"

When we begin to estimate their probable longevity, too, we find that they are not everlasting, that they have comparatively a short lease of life. Some have calculated that even the great rampart of the Andes will be all worked away in nine million years, which in the life of the world is less than a watch in the night.

If the average mind exaggerates the immensity and immutability of mountains, no less does it exaggerate their steepness We often talk of almost perpendicular slopes, but as a matter of fact very few slopes are steeper than an angle of 30° and those steeper than 40° consist usually of bare rock

While recognizing their relative smallness and their yielding to the gnawing tooth of time, geological science still retains a reverence for mountains as rocky records of mighty constructive and destructive forces that have molded and are still molding the earth, and finds in the making and unmaking of mountains a key and clue to the general mechanism of terrestrial change

A most interesting and fascinating question to science is how mountains were made Small though they be in comparison with the bulk of the earth, ephemeral though they be in comparison with the long ages the earth has existed, yet they are definite structural facts that require explanation, and must be made to fit into any theory of earth-origin and growth

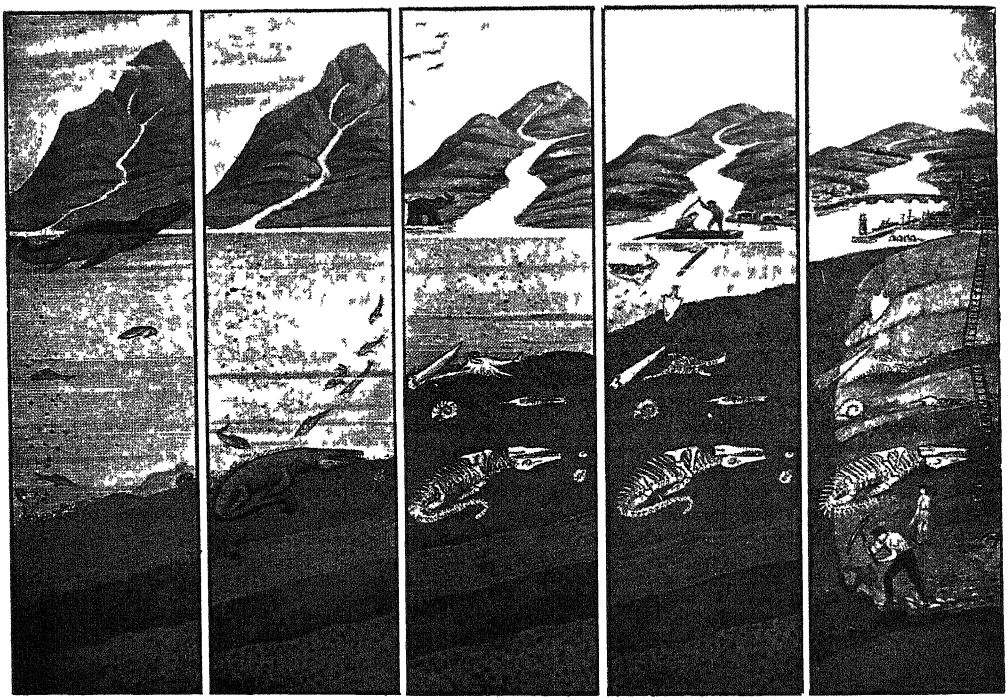
Let us, in the first place, look at the general geological character of mountains and mountain ranges Three kinds of mountains may be distinguished. First, those like Roraima, in Venezuela, seem to have been formed by the action of rain washing away the soil all round them. These may be called "mountains of denudation" Second, mountains such as Vesuvius, which are formed mainly of volcanic material. These may be called "mountains of accumulation". Third, mountains such as the Himalayas, which are built up out of sedimentary rocks. These may be called "mountains of elevation" Of the three classes, the third is much the most important, for to it belong all the great mountain chains of the earth.

The sedimentary nature of the great mountain ranges is a most astonishing discovery, for it means that these mountains — the Alps, the Himalayas — were once at the bottom of the sea So astonishing is it that only the most conclusive evidence could gain credence for the fact But the evidence is conclusive The great mountain chains are composed of layers of sediment that at one time must have been deposited on the bottom of the sea. Not only do they display a stratification — a series of layers that can only be explained as the

results of a precipitation through water — but many of them, as we have already stated, are built up out of the lime and shells of sea organisms, or contain fossils of certain sea creatures Marine fossils have been found in the Alps 10,000 feet, in the Rockies 11,000 feet and in the Himalayas 16,500 feet high

We start, then, with the very surprising fact that most mountains are made out of sediment deposited at the bottom of the sea Now, all the sediment that falls to the bottom of the sea, whether lime-shells, or silica, or anything else, has been carried, directly or indirectly, into the sea by rivers, and the rivers must have eroded them from previous hills, and so we reach the second astonishing fact that the rivers not only wear down mountains but carry the material for new mountains Just as certainly as all the bricks in a house were carted to its site, so certainly did the rivers convey to the sea the materials of the mountains The rivers gathered the material for the shellfish that make up the chalk cliffs of Old England, the rivers gathered the materials that make Mount Lebanon, Mount Everest and Mont Blanc and every cubic inch they must have obtained from previous mountains of previous and vanished worlds What cycles of destruction and construction there must have been!

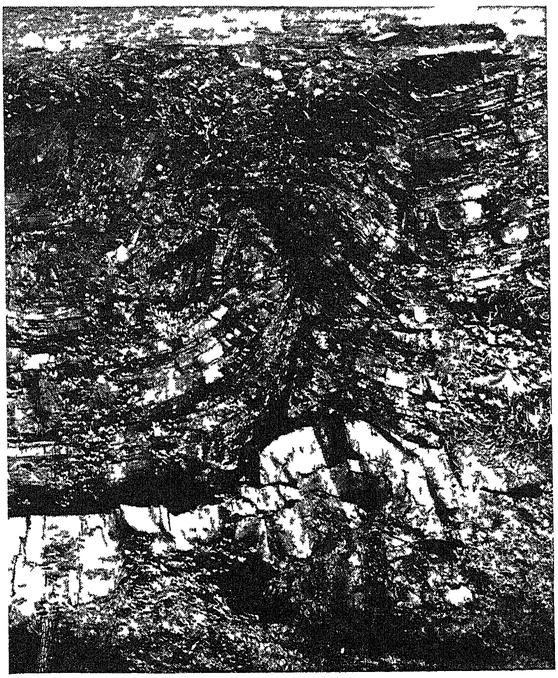
Remembering what we have already seen of the destructive energy of rivers and glaciers, remembering that the Ganges and the Brahmaputra bring down over 378,000,000 tons of mud yearly, and the Mississippi about 450,000,000 tons we can more or less easily believe that in time enough sediment even to make the thousands of miles of Andes and Himalayas would be precipitated to the bottom of the sea The difficulty begins when we try to understand how and why the tremendous load of sediment, all this mass of mud, was forced miles up into the sky



TRANSMIGRATION OF MOUNTAINS THE WORK OF A RIVER IN DEPOSITING MATERIALS ON THE FLOOR OF THE SEA FORMING A STRATUM AND IMBEDDING EXTINCT ANIMALS

When we examine these built-up mountains, we find that the various layers of sediment are almost always bent, crumpled and broken Originally, when deposited on the bottom of the sea, they must have

been flat and horizontal Now, we find them tilted up so that they are vertical We find layers that once must have been undermost uppermost, we find layers broken and their ends displaced for hundreds, perhaps thousands, of feet, we find, in fact, every kind of distortion and displacement It is evident, therefore, that the horizontal layers must have been elevated by very violent forces — forces sufficient to crumple and bend and break and displace layers of solid rock Most mountain ranges, moreover, show signs of having been several times down among the whales and up among the eagles, for we find layers of sediment that have been precipitated horizontally upon the other layers, which have been crumpled and displaced and broken All the evidence points to repeated subsidences and elevations How are we to account for these elevations and subsidences, and for the violence that caused and accompanied the movement? How are we to account for the crumpled layers of Mount Everest and Mont Blanc emerging from the ancient Tethys Sea?



FOLDED QUARTZITE AND SLATE, PAINT ROCK, N C

There is nothing to suggest that the stratified rocks have been bent and crumpled into mountain ranges by any internal violence acting upwards in a vertical direction, in fact, the crumplings and foldings of the rocks are of such

Photos U S Geological Survey

FOLDED QUARTZ IN GRANITOID GNEISS, CRANBERRY, NORTH CAROLINA

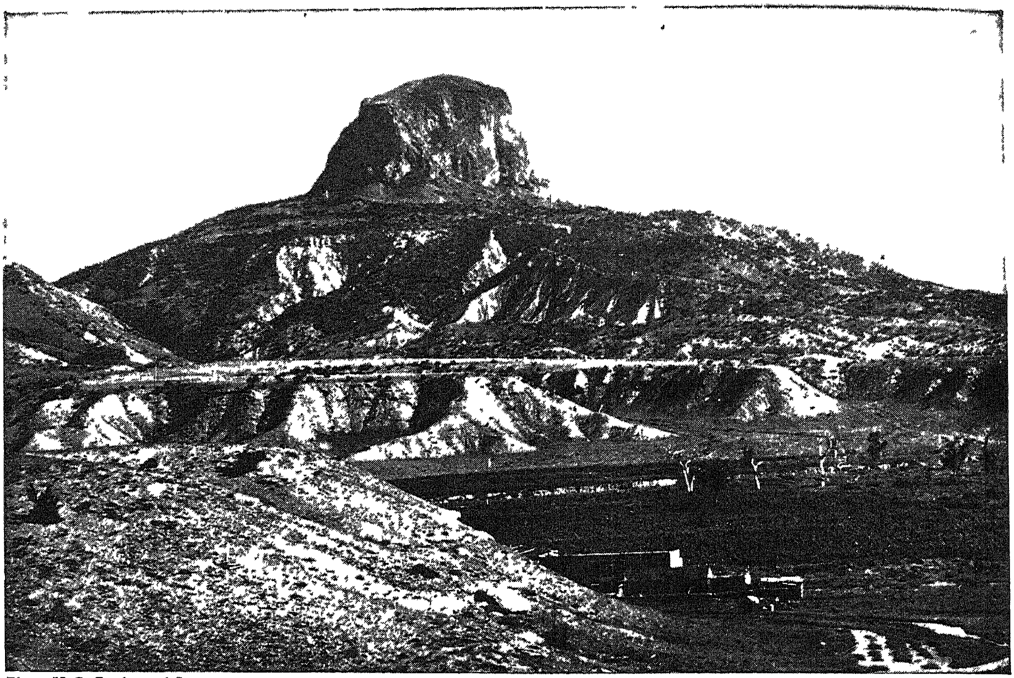
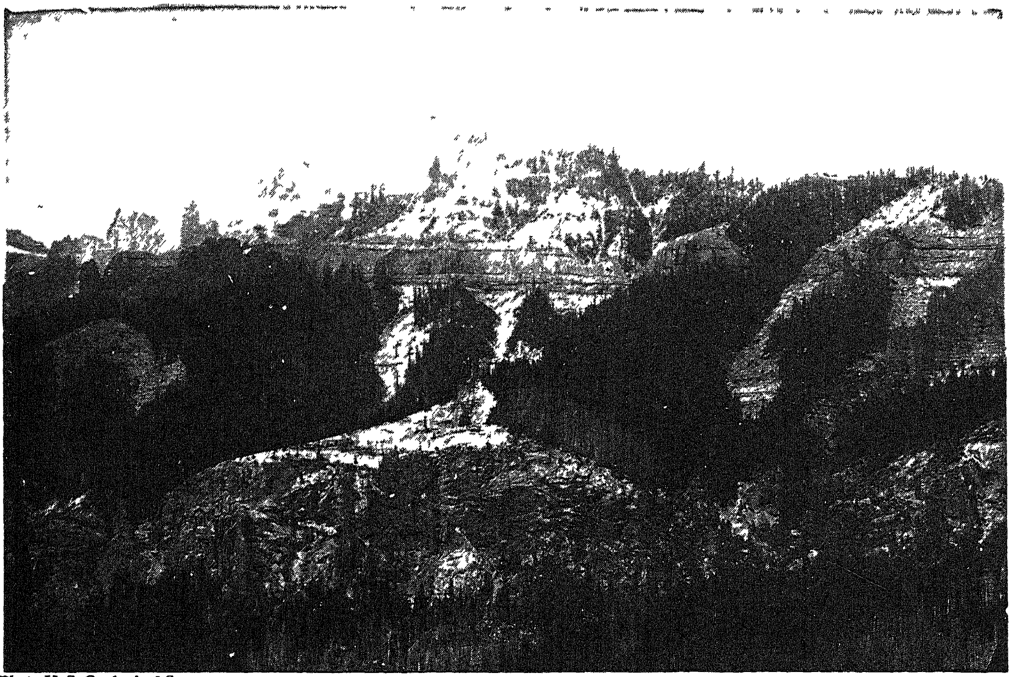


Photo U S Geological Survey

MOUNTAIN OF DENUDATION — VOLCANIC PLUG IN SEDIMENTARY SANDSTONE, CABEZON BUTTE, N. M.

a nature as to negative such a supposition. Everything suggests that the rocks have been bent and crumpled by lateral pressure, much as we might crumple a tablecloth by moving the right and left index-fingers together over it, so as to kink and crumple the cloth between them. Sir James Hall illustrated the process by putting layers of cloth under a weight and then applying lateral compression. The result was crumplings closely resembling those of the Silurian strata of the Berwickshire coast. Professor Fabre, of Geneva, fixed some layers of clay upon a tightly stretched band of india-rubber, and demonstrated that when the band of india-rubber contracted the layers of clay showed contortions and inversions and dislocations quite like those of a great mountain-chain. H. M. Cadell further elaborated the experiment by using layers of plaster-of-Paris, sand and clay, and reproduced crumples and dislocations resembling those seen in the rocks of the Northwestern Highlands of Scotland. And Bailey Willis, professor emeritus of geology at Leland Stanford University, has carried out similar elaborate experiments in his investigation of the "mechanics of Appalachian structure".

Lateral pressure, then, is admitted to have caused the crumplings of the earth's crust, and the consequent elevation of mountain ranges. So far, there is no difference of opinion, and no difficulty Differences of opinion and difficulties begin when we endeavor to find the precise cause of the lateral pressure. In a general way, the cause of the lateral pressure is a shrinkage of the earth's interior owing to loss of heat through radiation. Since the crust does not shrink correspondingly, it becomes too large for its shrunken contents, with the result that lateral pressure is produced, followed by folding and crumpling It has been estimated that the crumpled folds of the Alps represent a shrinkage of seventy-four miles in the earth's circumference; that the crumpling of the coast range of California represents a shrinkage of ten miles; and that to produce all the mountain ranges the earth's circumference must have shrunk about two hundred miles altogether. The lateral pressure produced by such shrinkage must have been very great, since we



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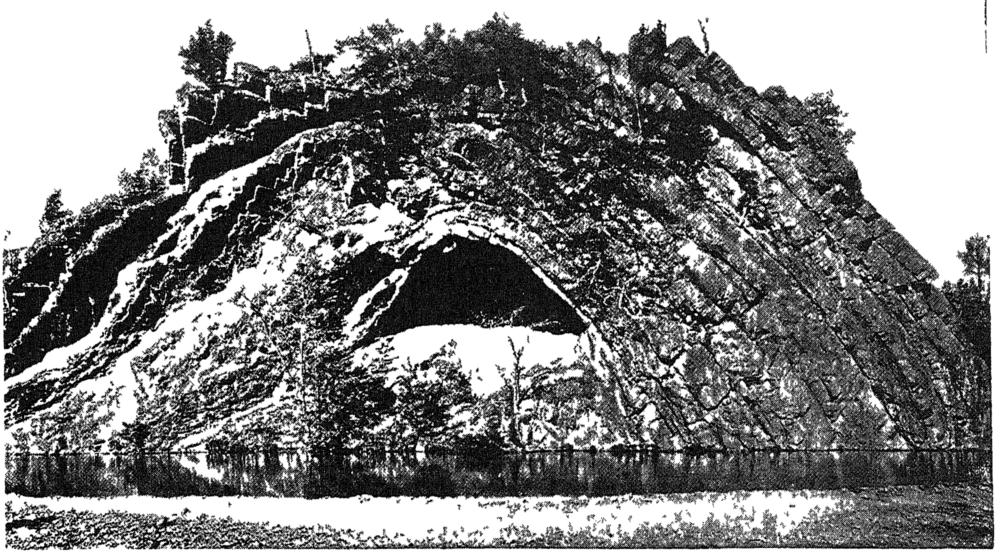
EROSION MOUNTAINS — THE CASTLE, WEST ELKS MOUNTAINS, COLORADO

find in places gigantic horizontal displacements whereby large mountainous masses of the terrestrial crust have been thrust over younger formations, in some cases for miles. The force of the pressure, too, is shown by the fact that clays and sands in the center of the folds have been converted into hard, crystalline rock.

Granted that the mountainous corrugations of the earth's crust have been produced by enormous lateral pressure due to shrinkage, it still remains to inquire why the earth's crust buckled at these particular parts, and why the buckling parts were so often submarine. Why were these parts squeezed and apparently repeatedly squeezed into corrugations? The wrinkles on an apple due to contraction radiate about in all directions. Why are the mountain wrinkles of the earth displayed in certain definite lines? It seems rather a begging of the question simply to say that the mountain-chains and continental areas were lines and patches of weakness in the earth's crust. What we wish to know is just why the crust was weak enough in certain places to buckle into mountain-chains and continents.

One most interesting suggestion was made by Professor George Darwin, who pointed out that the earth was originally more flattened at the poles, and that as it became more spherical the crust would necessarily become too large for its contents and would shrink. He noted, further, that a shrinkage due to this cause would place most of the mountain-chains within the zone of the equatorial bulge. He explained the direction of the mountain-chains as the result of lunar tide influence and rotation, which together would exert a screwing action on the earth's crust, and produce corrugations at right angles to the direction of greater pressure. "In the case of the earth, the wrinkles would run north and south at the equator, and would bear away to the eastward in northerly and southern latitudes, so that at the North Pole the trend would be northeast, and at the South Pole northwest. Also, the intensity of the wrinkling force varies as the square of the cosine of the latitude, and is thus greatest at the equator and zero at the poles. Any wrinkle when once formed would have a tendency to turn slightly, so as to become



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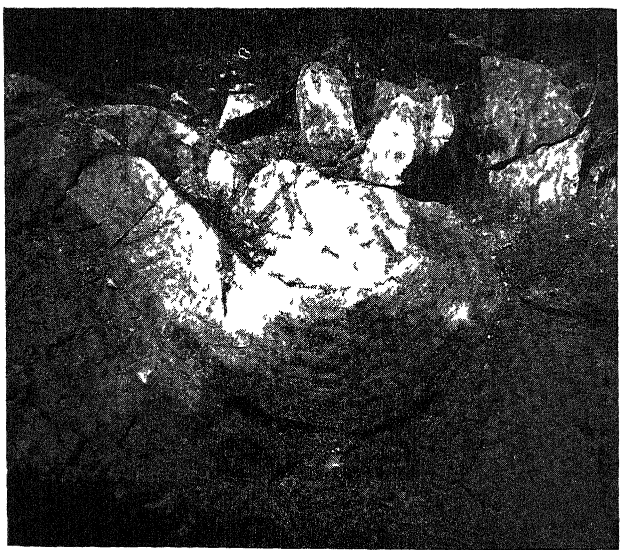
CLASSIC ANTICLINE — RED SANDSTONE, ROUNDTOP, MARYLAND

more nearly east and west than when it was first made."

Interesting as this theory is, it is hardly quite satisfactory, since the forces Professor Darwin invokes could have acted effectively only in the youth of the world, and before the time of the making of modern mountain-chains Moreover, the theory does not account for the evident relationship between sedimentation and mountain formation. Millions of years of sedimentation preceded the emergence of the Alps and Carpathians and Himalayas from the Tethys Sea The three great upheavals in the North American continent, known as the Huronian, Animikean and Keweenawan, were the resurrection of sediment 18,000, 14,000 and 50,000 feet deep respectively. "The region," says Dana, "over which sedimentary formations were in progress in order to make finally the Appalachian range reached from New York to Alabama, and had a breadth of 100 to 200 miles, and the pile of horizontal beds along the middle was 40,000 feet in depth. The pile for the Wasatch mountains was 60,000 feet thick, according to King The beds from the Appalachians were not laid down in a deep ocean, but in shallow waters, where the gradual subsidence was in progress; and they at last, when ready for the genesis, lay in a trough 40,000 feet deep, filling the trough from brim to brim." The Laramie range, extending from southeastern Wyoming into Colorado,



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SYNCLINAL FOLD IN DOLOMITE, EMBREEVILLE, TENNESSEE

a curved spur of the great Rocky Mountain system, was reared from sediment 50,000 feet deep. Whatever, then, the explanation of mountain-chains may be, it has to account for their sedimentary antecedents A very interesting attempt to show the casual connection between mountain formation and sedimentation was made by Babbage According to his theory, the heaping up of sediment on the ocean floor must cause a rise in the temperature of the floor, since we know that the temperature of the earth increases with depth A thousand feet of rock, for instance, on the ocean floor, would raise the temperature of the crust below it by about 20° F. For like reasons, the denudation of the land must lower the temperature of the continental crust The buckling of the sedimentary layers, then, according to this theory, is due to the enfeeblement of the submarine crust by superheating Some geologists have added to this theory the supposition that the load of the sediment actually depresses the ocean floor, and that the denudation of the mountains leads to a rise of the unloaded continental crust; but, as Geikie remarks, "to suppose that the removal or deposit of a few thousand feet of rock, such as the mass of a mountain belt like the Alps, should so seriously affect the equilibrium of the crust as to cause it to sink and rise in proportion would evince an incredible degree of mobility in the earth which would surely be manifested in other directions". Babbage's theory, involving the cooling of the exposed crust and the heating of the ocean floor, seems plausible, but it will not stand examination After all, the sedimentary layers of the ocean floor merely replace in position, as surface layers, the igneous layers, and are exposed to practically the same heat. Why, then, should they bend and buckle under lateral pressure? A modification of Babbage's theory was proposed a few years ago by Mallard Reade. He supposes that the sediment plastered on the floor of the sea acts like a strip of non-conducting material on the surface of a cooling ball of metal, retaining and raising the heat of that part of the earth's surface which it covers, and being in time heated itself above the average temperature of the crust. The excess of heat makes the sediment and underlying rock expand. Expansion laterally and downwards is impossible, so it expands upwards, as a cake expands upwards on being baked, and the result is the mountain ranges and continents now being worn down.

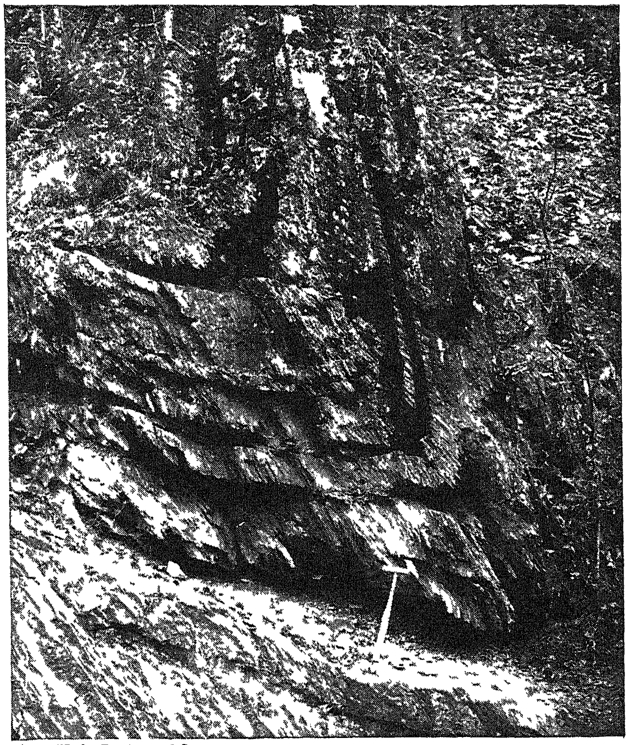


Photo U S Geological Survey

FOLDING AND CLEAVAGE IN BANDED SLATE, WALLAND, TENN.

The flaws in this theory are that it does not account sufficiently for the lateral pressure which has certainly been at work on the mountains, and that the cause it supposes is not commensurate with the effects. As Bonney remarks: "The folding of a chain like the Alps is so marked, and its scale so gigantic, that the difference of temperature and consequent expansion

which would be produced by the accumulation on that area of a few thousand feet of rock seem quite inadequate as a cause."

Yet another modification of Babbage's theory has been suggested by Professor Joly, who calls radium to his aid. He has shown, by actual estimates of radium, that "in the deposition of sediments — their uplifting into mountain-chains, their subsequent removal, and their re-disposition elsewhere — there is a continual convective movement of radioactive materials on the surface of the earth. Around the margins of all the great continents, where the sedimentation necessarily takes place to the greatest extent, the result of this convection is the accumulation of vast amounts of radioactive materials." And he holds that the accumulated radioactive material in the sediment is sufficient to raise its temperature, and to render it more liable to corrugation under the lateral pressure of the contracting earth. He calculates that a deposit only four kilometers deep reduces the effective strength of the earth's crust by 10 per cent. He sums up the matter with regard to mountain elevation thus. "The whole theory is of the simplest kind. Given a stressed crust and a local source of heat applied above, while the normal heat of the earth flows upwards from beneath, and the area where these conditions exist must necessarily become the first place of yielding and flexure, as naturally as the rupture of the chain occurs at the weakest link. Under these conditions, accordingly, we find, associated with great accumulations of radioactive sediments, bending and fracture of the crust, with the attendant phenomena of earthquake and volcanoes."

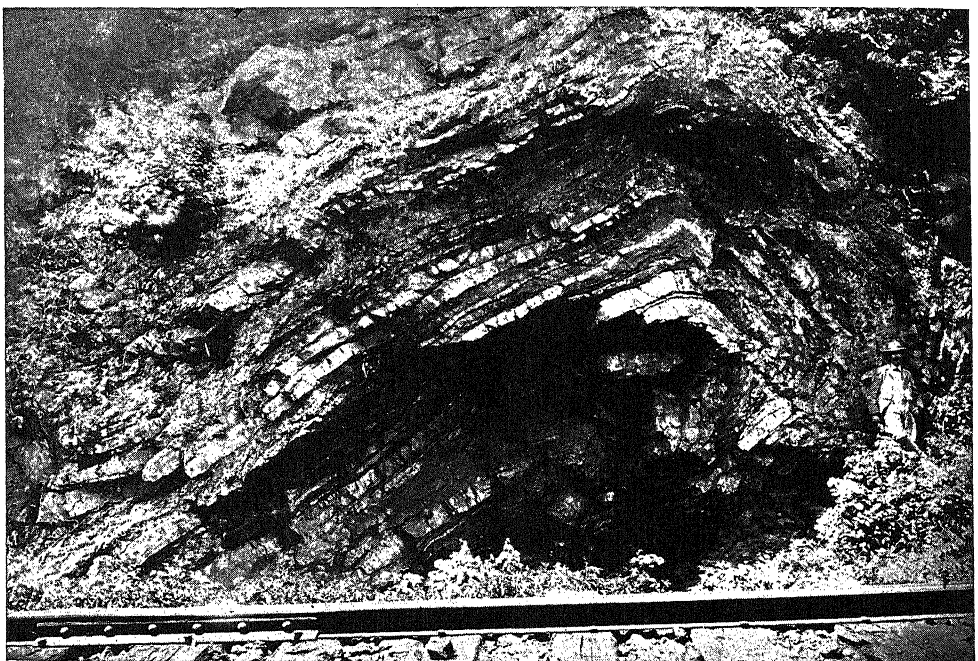


Photo U. S. Geological Survey

ANTICLINAL FOLD IN SANDSTONE, PANTHER GAP, VIRGINIA

However the mountain-chains were raised, one thing is quite certain, and that is that in their original condition they must have been very unlike the mountain chains now. They must have been very much less picturesque, and much more like the long linear corrugations we see on plates of corrugated iron. There must have been long level ridges, the anticlines, alternating with long valleys, the synclines; and, of course, at first they would be bare rock, without grass, or tree, or heather to

break their brown and gray undulating monotony.

It is difficult to realize how much mountains have altered since their birth. Not only are the ranges now cut up into peaks of all shapes, but they are not half so high as they originally were. Wind and rain, frost and snow, have been at work for thousands of years, and the wear and tear has been tremendous. From the ancient mountains of Wales fifteen or twenty thousand feet have been removed. From the mountains in the Lake District in England and from part of the Appalachian range of the eastern United States, no less than 26,000 feet — a little less than five miles, that is to say — have been worn away. Above the Simplon at one time there was a sedimentary layer at least 50 or 60 thousand feet deep. The Laramie range in the Rockies would be 32,000 to 35,000 feet high today if it had not been eroded away.

It is an interesting fact that the original ridges or anticlines wear away much faster than the troughs or valleys or synclines between them. The reason of this is that the layers in a syncline are arranged like a pile of saucers set one within the other, right side uppermost, while the layers in an anticline are like a pile of saucers piled upside down. It is plain that the anticlinal arrangement is much more easily broken up than the synclinal, because in the synclinal arrangement the saucers hold each other together. So much more rapidly are anticlines eroded than synclines that in some cases the original relationship of anticline and syncline is reversed, and the syncline becomes the mountain crest and the anticline the valley. In the case of the Appalachian Mountains, for instance, this reversal has occurred, and the mountain summits are synclines and the valleys anticlines.

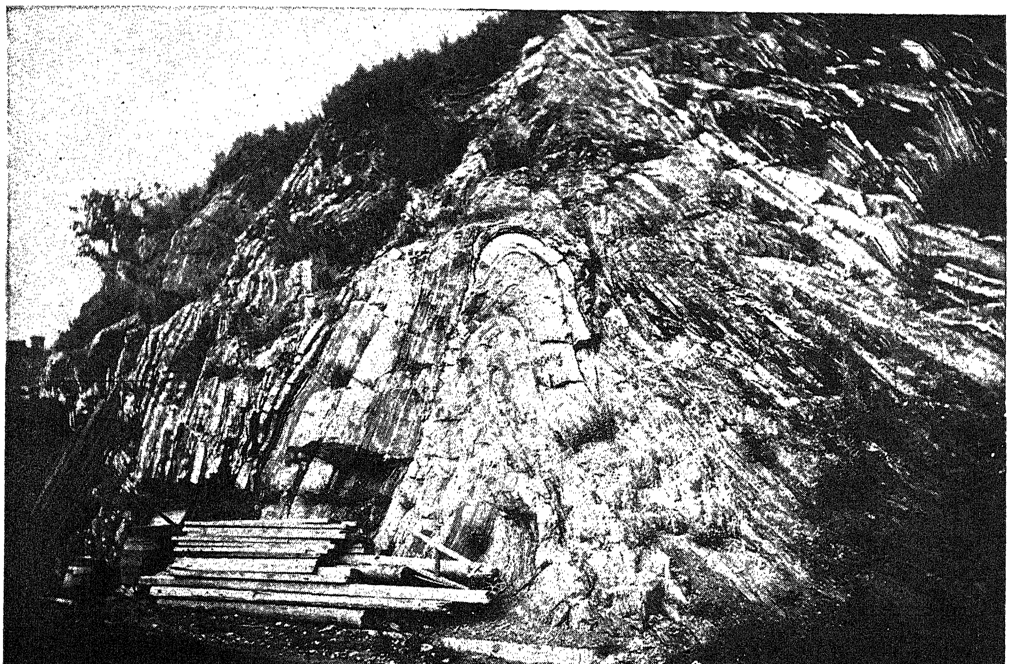


Photo U. S. Geological Survey

ANTICLINE, LEWIS, QUEBEC

It must be noticed that the rate of denudation of mountains of elevation, and the shape to which they are worn, depends not only on the direction of the strata composing them, but also on the material of which they are composed. Limestone rock is comparatively quickly worn away, and assumes rolling curves, or in some instances takes the shape "of ruined

masonry, suggesting crumbling battlements and tottering turrets". Granite does not resist denudation so well as might be expected; it has chinks in its armor in the shape of horizontal and vertical joints, and is often worn into great square blocks. Granite mountains have rarely sharp, jagged peaks; they are nearly always rounded and massive. Most of the high, sharp, jagged peaks are composed of gneiss and mica-schist. All the aiguilles of the Alps — the Wetterhorn, the Matterhorn, the Weisshorn, the Aiguille Vert, the Aiguille des Charmoz, Dent du Midi, Dent de Morcles, etc. — are produced by the weathering of gneiss and mica-schist.

When we say that a certain mountain range has been worn down for 10,000 feet, it does not necessarily follow that the mountain tops are 10,000 feet nearer sea level, for in many cases as the top of the mountain is worn away its base is elevated, and thus the mountain, despite great denudation, may remain about the same height. Even at the present day such a compensatory rise is known to be taking place in various parts of the world. The greater part of Scandinavia is slowly rising out of the sea, at the rate of a few feet a century, so that in some districts the pine-trees have been lifted into regions of perpetual snow and have been killed by the cold; while around the lakes of southern Sweden are found oyster-shells that have once been in the sea. In California there are raised beaches as high as 1500 feet above the present sea level; the coasts of Scotland are marked by a series of terraces one above the other, to the height of 75 feet, testifying to rises of the land; and there is a famous raised beach in North Wales 1357 feet high. Nova Zembla, Spitzbergen, Siberia, Northern Greenland, the western coast of South America, New Zealand, Japan, all show signs of upheaval. Accordingly, even now the mountains in many lands are slowly being upraised, and it is possible that this process of elevation, still going on, more than compensates for weathering and denudation.

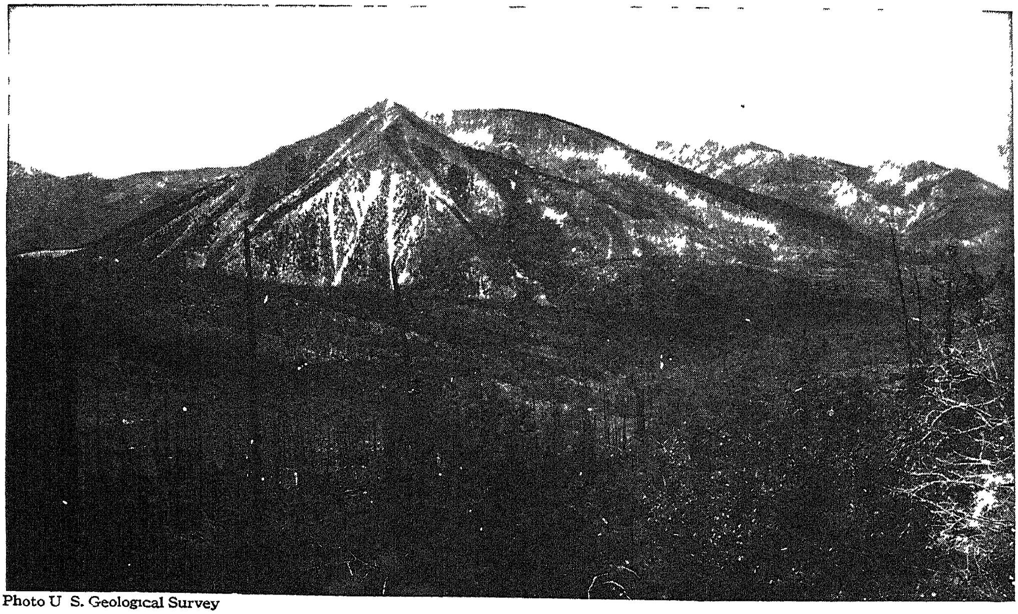


Photo U. S. Geological Survey

UNCOVERED IGNEOUS INTRUSIVE MASS

We have not yet considered the question of the rate of the uprising of the great mountain-chains. Did they uprise gradually and slowly, as Scandinavia has been rising for the last few hundred years, or were they upheaved with volcanic violence all of a sudden? In some instances earthquakes have been known suddenly to raise and depress large areas of land to a

quite considerable extent. After an earthquake in 1822, the coast of Chili was upraised for three or four feet; and after an earthquake in 1762, sixty square miles of land were suddenly submerged in the sea. Did the Alps and Himalayas rise slowly inch by inch from the bottom of the sea, or was their upheaval a matter of a few minutes?

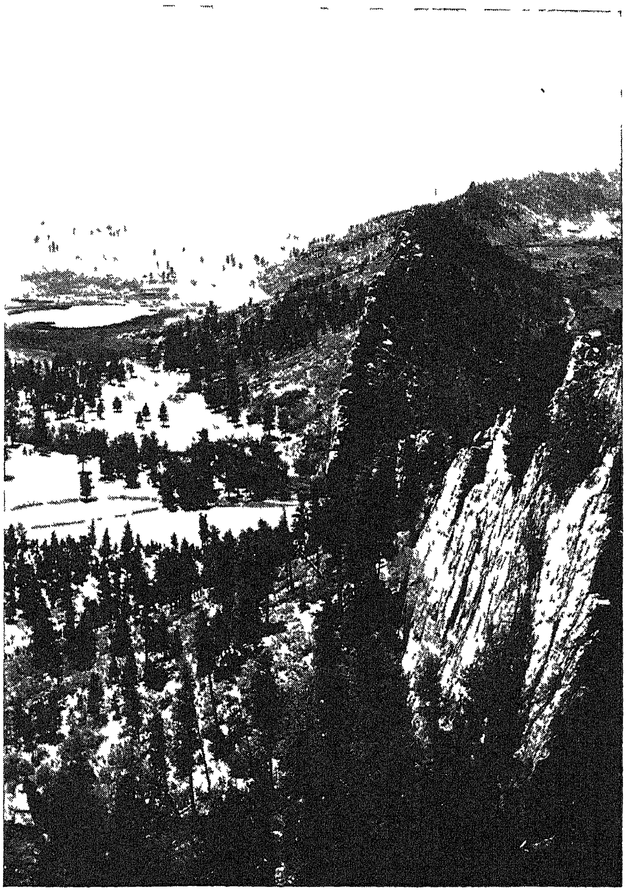
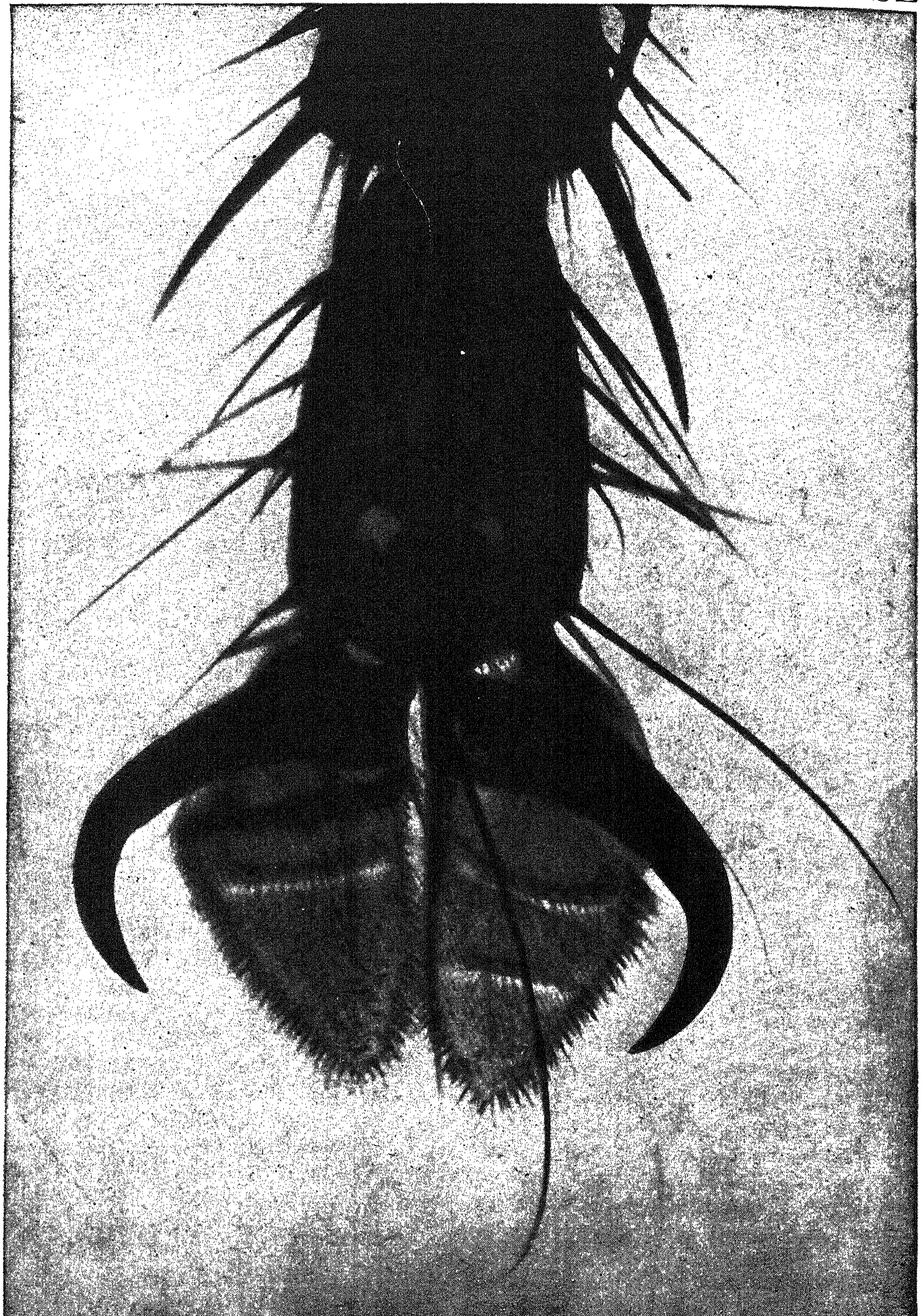


Photo U. S. Geological Survey
HOGBACK MOUNTAIN, SOUTHERN COLORADO

Probably the elevation of the mountains was intermittent, and at times steady and slow, like the elevation of Scandinavia, and at times sudden and paroxysmal, like the elevation of the Chilian coast. The tremendous crumpling and folding of the rocky layers of the mountain chains certainly seems to indicate violent and paroxysmal upheavals, but, on the other hand, there are proofs that great elevation must have occurred gradually without any violence at all. An instance of this quiet elevation is seen in the elevation of the Uinta Mountains, which was so gentle "that the Green River, which flowed across the site of the range, has not been deflected, but has actually been able to deepen its canyon as fast as the mountains have been pushed upward". And in the Himalayas "rivers still run in the same lines as they occupied before the last gigantic upheaval of the chain".

Mountain-chains, then, probably rose, as a rule, gradually, with occasional paroxysms of violent and rapid upheaval. And now all these modern mountain-chains are being gradually deposited as sediment in the sea, and in time the sediment will again be raised into new mountain-chains. The Amazon, the Mississippi, the Brahmaputra and all the great rivers are all busy mountain-making. Many of the processes of nature exhibit a cycle of destruction and construction, but none is more dramatic than the cyclical destruction and construction of mountains. Think of it! Mud at the bottom of an ocean rising inch by inch, foot by foot, till eventually it is a mighty range of snow-clad peaks, and then the great peaks, inch by inch, foot by foot, eroded away, and collected as mud to await new reconstruction! Thus to and fro swings the great geological pendulum!

A CARRIER OF DEATH-DEALING DISEASE



THE FOOT OF THE COMMON HOUSE-FLY, HIGHLY MAGNIFIED, SHOWING ITS CLAWS, PADS AND BRISTLES, UPON WHICH DISEASE BACILLI ARE CONVEYED TO MAN'S FOOD MATERIALS

THE CONQUEST OF DISEASE

The Discovery and Arrest of the Spread, by Mosquitoes, Flies, Fleas and Ticks, of Dreadful Epidemics

THE EARTH MADE HABITABLE BY SCIENCE

FOR countless ages the mosquito has barred Africa from civilization, which otherwise would most certainly have flowed into the "Dark Continent" from its home in Asia sooner than into Europe. But malaria is not the only reason for which man and the mosquito are at enmity, though it is a million times more than sufficient. We now know that there is, at any rate, one other disease, terrible in its fatality and in our impotence against it until the present century, which is conveyed from man to man by the mosquito, just as is malaria.

This is yellow fever, a disease that for ages had proved a scourge in certain tropical and subtropical regions; for none knew its cause or its mode of dissemination, and consequently no one knew how to check its ravages. It was not until the year 1900 that measures were discovered for the control of yellow fever and even then the actual cause of the fever remained unknown. From time to time various investigators reported finding the causal agent of this disease but these findings, one after another, proved erroneous. In 1919, the careful, patient work of a Japanese investigator, Dr. Hideyo Noguchi, of the Rockefeller Institute for Medical Research, was thought to have discovered a spirochæte, *Leptospira icteroides*, as the cause of yellow fever. It was later shown that this spirochæte caused infectious jaundice, or Weil's disease, the symptoms of which closely resemble those of yellow fever.

Half-way through the nineteenth century Beauperthuy rightly guessed that mosquitoes convey disease. He was right as regards malaria, and he was more than ever right as regards yellow fever, for he actually named the particular kind of mosquito — not an anopheline, as in the case of malaria — which alone conveys the disease. In 1881 Dr. Charles Finlay also incriminated the right mosquito, declaring that it conveys the then unknown infection *from man to man*. Finlay was right, but for long before and after his time this question of the transmission from man to man was the puzzle. For, in fact, there was no evidence that the disease is contagious. Some brave students had tried to infect themselves — or, rather, tc demonstrate that they could not be infected — by contact with clothes, etc., which might be expected to convey the contagion; in no case was the disease transmitted. And yet no one could observe the facts of the disease at large without inclining to the view that the infection spreads "from man to man".

In England they appointed a royal commission to study the disease in order to decide what the quarantine laws should be. The commission reported against quarantine, as useless, and declared that "in an epidemic the most rigid seclusion affords no protection, that great success attends removal to a non-infected district, that the exciting cause, whatever it is, is local and endemic". Here and there observers were to be found who said that the disease is not contagious, though the infection does somehow get from the sick to the sound; and some of them remarked on the curious fact that an interval of time seemed to be required before the unknown could pass from one man to another. Why this interval of time, and where was it spent?

Following the order of our knowledge, let us briefly look at the facts of yellow fever, or "Yellow Jack", as they were known at the end of the nineteenth century. Like malaria, the disease has played a great part in history. The buccaneers of long ago, and, later, the British regulars, when they were engaged in conquering in the West Indies and on the Spanish Main, found in it an enemy which time and time again swept pioneers and soldiers away like so many flies. The historian Prescott wrote of it, that the moment a town was founded or a new commercial center created, an explosion of the latent malignity of the poison in the air was certain to occur. The disease was known to the Aztecs, and according to Humboldt it existed as early as the eleventh century. The followers of Columbus were cursed by it at San Domingo; and Columbus had to write to the king of Spain about the disease, which he attributed to "peculiarities in the air and water" in the new country. The "pest of Havana", described as early as 1620, was doubtless yellow fever, which is believed to have carried off one-fourth of the population of that town for centuries. But now there has not been a case, let alone a death, in Havana for years

The work of the United States army surgeons in mastering yellow fever

The new era began in 1900, when the United States sent a commission of Army surgeons, consisting of Drs. Reed, Carroll, Agramonte and Lazear, to Cuba to study the disease. Influenced by the theory of Finlay and the work of Ross upon malaria, they began at once to search in the right direction. Dr. Lazear died of the disease, as did Dr. Myers, sent out from Liverpool. The various workers, among them, proved that the clothes and excretions of the patients were not infectious — by sleeping in the patients' clothes, upon their contaminated bed-linen, etc.; they proved that the peripheral blood of the patient contains the agent, unknown at that time, only during the first three days after he is infected, and that if he be then bitten by one particular species of mosquito, *Stegomyia calopus*, and by that alone, after twelve days, but not before, that mosquito becomes capable of conveying the disease to any healthy man whom it chances to bite

And now, of course, we know where we are. All manner of agents have been blamed in the past, from droughts and floods and "pestilential swamps" to the stone ballast of ships, thousands of tons of which have been disinfected or thrown into the sea. Before the work in Havana, the U. S Army doctors had already transformed, in many essential respects, the sanitary conditions of the city, and had freely used the ideas of Pasteur and the practice of Lord Lister in the form of antiseptics and disinfectants, in order to arrest the yellow fever. Nothing affected the disease in the least It ceased only after employing methods directed against the mosquito — viz , fumigation, screening and destroying the breeding-places of the larvæ. The following is a summary of the new knowledge concerning yellow fever as set forth in Dr. E. R. Stitts' "The Diagnostics and Treatment of Tropical Diseases ".

1. The course of the disease is a spirochætol organism, *Leptospira icteroides.*

2. Man suffering from yellow fever is, during the first three days of his illness, the *reservoir.*

3. From this reservoir one species of mosquito, *Stegomyia calopus*, becomes infected, and after the twelfth day becomes the insect *carrier*, or transmitting agent of the disease.

4. The reservoirs and the carriers are both necessary for the spread of the disease.

5. Method of attack:

(*a*) Screen effectively all patients suffering from the disease, at least during the first three days of illness.

(*b*) Prevent entry of reservoirs (quarantine measures, etc.).

(*c*) Exterminate the carrier (anti-adult mosquito measures, screening, fumigation, etc.; anti-larval measures, control of water supply, oiling, drainage).

Stegomyia calopus, the larval and adult forms of which are here shown, has long been familiar in the tropics. It is a domestic mosquito, like our own domestic fly, and is often called the "cistern mosquito", because it breeds in cisterns and other artificial receptacles that contain water about dwellings. It also breeds in ground pools about habitations where the water is sufficiently polluted. It prefers filthy water, especially that charged with animal matter. The female alone sucks blood.

The extraordinary effects of American as compared with Spanish control

The Spaniards did nothing for Havana, except in so far as their ancestors contributed to the discovery of America, and thus to the American control, which began when yellow fever had been causing an average number of two deaths every day in Havana since 1853. But now the disease has been annihilated. In April, 1909, when the "Bulletin of Public Health and Charities of Cuba" was published, the republic was declared "free from smallpox, yellow fever and bubonic plague". In New Orleans in 1853, an outbreak of yellow fever swept off more than 3900 of the inhabitants. Again in 1878, a second epidemic of this fever raged in this same city in which there were recorded 13,086 cases with a death toll of 4000. When, however, in 1905 another menacing epidemic of this dreadful disease threatened the city, our health authorities, thanks to the work of Reed and his colleagues in Cuba, knew what to do and forthwith set about doing it. Dr. J. H. White of the U. S. Public Health and Marine Hospital Service was promptly ordered to New Orleans and placed in charge of the situation there. He was ably assisted by Dr. Souchon, President of the Louisiana State Board of Health, Dr. Kohnke, Health Officer of the City of New Orleans, and a committee of the Parish Medical Association. Under the direction of this able body of physicians a vigorous campaign for the stamping out of the disease and the destruction of the mosquitoes responsible for its spread was prosecuted.

Campaign for the prevention of yellow fever in New Orleans

They formulated and published the following directions for carrying on the fight, in which they were assisted by the various agencies in the city:

1. To keep empty all unused receptacles of water in every house, and allow no stagnant water on any premises.
2. To screen all cisterns after placing a small quantity of insurance oil (a teacupful in each cistern) on the surface of the water.
3. To place a small quantity of insurance oil in cesspools or privy vaults.
4. Sleep under mosquito nets.
5. Wherever practicable, screen doors and windows with wire screen of close mesh.

This epidemic in which the first case detected was reported on July 18, and in which a total of 3404 cases were recorded with a death toll of 452, was declared ended on October 26, a period of less than one hundred days. When we consider the conditions that prevailed in New Orleans at that time, a dense population, open drains and hot sultry weather, this triumph is one of the most notable in the history of medicine; for frost, which heretofore had been the only agency competent to check such an epidemic, did not occur that year in New Orleans till December 4. Men of science, unaided by climatic change, had stamped out the disease by an exterminating war on the mosquito that carries it.

Complete extermination of yellow fever where it had meant almost certain death

But the most remarkable and important case of all, for the future history of mankind, is the campaign against this mosquito in the Panama Canal zone. The plan of campaign was begun there from the moment that the Isthmian Canal Commissioners took over its administration. It consisted in rigorously prohibiting the keeping of stagnant water, and in screening, house-to-house inspection and the infliction of fines if larvæ were discovered.

The disease has been banished; and as early as 1908, Colonel Gorgas, then Surgeon General of the United States Army, to whom Havana also owed so much, could write that "it is now more than three years since a case of yellow fever has developed in the isthmus, the last case occurring in November, 1905. The health and sick rates will compare favorably with most parts of the United States." The verdict of history upon this tremendous enterprise, now completed, will be that the essential difference between the disastrous and appalling failure of the French in the nineteenth century and the success of the Americans in the twentieth was due to two factors and two alone — first, the anti-mosquito measures by which malaria and yellow fever were banished from the zone; and second, the prohibition of the sale of alcohol for an area extending for several miles on each side of the canal throughout its entire length.

Another tropical fever, called "dengue", which is caused by an ultra microscopic, filterable virus, is carried by mosquitoes. It was formerly believed that *Culex fatigans* was the species that carried this disease, but recent investigations indicate that it is the same *Stegomyia calopus* that spreads yellow fever.

We turn now to another group of insects, widely classed as "flies", and to a terrible disease, for which no quinine nor any known drug yet avails, and which is popularly called the "sleeping sickness", from the increasing stupidity and dullness of the patient, due to the attack of the disease-poisons upon the brain. Here, as in the case of malaria, the causal parasite is definitely known. Like the malaria parasite, this belongs to the animal kingdom. It is a microscopic creature, with a somewhat spiral, ribbon-shaped body, and is hence known as a trypanosome. Certain species of trypanosomes have been known for more than forty years as blood-parasites of several of the lower animals. But it was not until 1902 that a trypanosome was proved, by Dr. Castellani, to be the cause of sleeping sickness, which is now technically known as "trypanosomiasis".

The search for the cause and cure of the sleeping sickness

This most fatal malady is apparently of new development, on any large scale, in Africa. The exploitation of the continent by trade, and the movement of large bodies of natives from point to point, have led to the spread of the disease on an appalling scale Whole communities on the Congo and elsewhere have been wiped out, and in the Uganda Protectorate there have been hundreds of thousands of victims But all real knowledge makes easier and quicker the acquisition of more knowledge — "it is only the first step that costs" The work of Ross, following upon that of Pasteur and Laveran and Manson, had given us the key to malaria, and had incidentally shown how much may be learned regarding human disease by the study of disease in the lower animals.

The distinguished investigator David Bruce had already shown that the fly-disease of horses and cattle known as "nagana" in Africa is conveyed from one animal to another by the bite of a species of tsetse-fly, *Glossina morsitans* — the "biting Glossina". Then, having found the trypanosome in sleeping sickness, he had to seek a fly, probably a tsetse-fly, which might convey the parasite in this case also

The campaign against the fly diseases of horses and cattle

The "carrier" was soon found in the form of the particular tsetse-fly which is known as *Glossina palpalis*. Only where that fly is found do we find sleeping sickness, just as we find malaria only where there are anophelines, and yellow fever only where there is a certain species of mosquitoes of the genus Stegomyia.

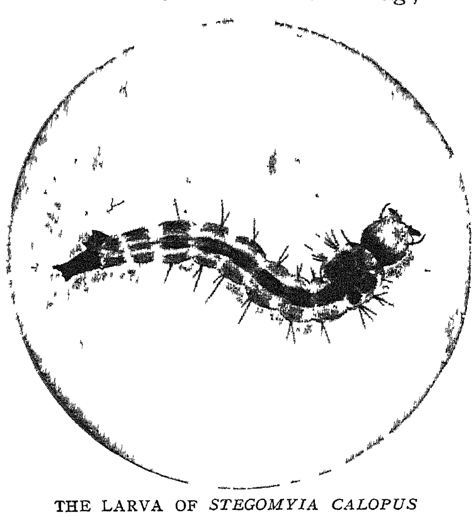
As in the latter case, it was further proved by Bruce and others that the trypanosome uses the tsetse-fly as a true host, in which it passes part of its life-cycle. It is not that the fly merely happens to have some of the trypanosomes hanging about its proboscis, and so may infect a fresh person. On the contrary, a period of from two to three weeks is necessary before the development of the trypano-

some in the fly enables it to infect a new human being. This is not a question of merely zoölogical interest. It does not mean that *any* biting fly, which happens to bite a patient with trypanosomes in his blood, will avail to convey the disease. As in the cases of malaria and yellow fever, a specific insect host is required for the specific parasite; and just as the extermination of malaria or of yellow fever would be well-nigh hopeless if every common Culex mosquito could convey it, so here we realize that we may succeed because only one particular insect need be attacked, and if we examine its habits we shall find a vulnerable point.

The plan of campaign in this case has been, and is, to attack the fly less in its adult than in its larval stages. Its breeding-place is the strip of underbrush extending for not more than thirty yards from river-banks. Here the young larvæ find the humidity and shade they require Find the exact facts in this fashion, and proceed to burn down the underbrush, and the flies will be interfered with. Here, as in the previous cases, precise knowledge narrows the limits of what is necessary. "It is not necessary to cut down forests, any more than it is necessary to drain lakes and run rivers dry in anti-malarial operations. All that is essential is to go for the chief breeding-grounds round man, and to let the forests take care of themselves." Professor Koch satisfied himself that certain wild animals, such as the crocodile, are preyed upon by the glossina, and that it would be worth while to attack them. Hunters of big game have, on these grounds, asked for relaxation of the restrictions at present placed upon their sport. But experience has shown that the very indirect method of attacking, say, crocodiles because the tsetse-fly may occasionally suck their blood is quite superfluous, even if it were really useful.

Much can be done in other ways, as by avoiding the bite of the fly, and also, perhaps, by the use of drugs. There seems little doubt that certain organic combinations of arsenic have the power of killing the trypanosomes in the blood. Such combinations are the German secret preparation "Bayer 205", "atoxyl", and probably the "606" or salvarsan later introduced by Professor Ehrlich for attacking another form of animal parasite, not very distantly related to the trypanosome, which has been proved to cause that terrible scourge of mankind, syphilis.

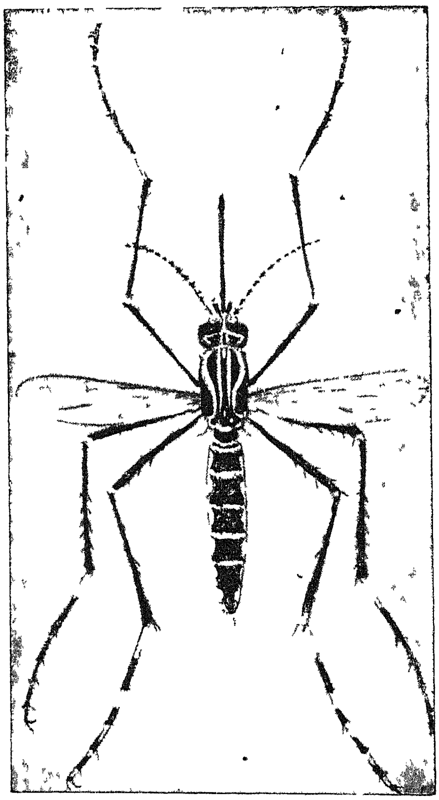
These therapeutic experiments are no doubt very interesting and may often have prolonged life, but their scope is limited. For one thing, the trypanosomes learn to take refuge in the nervous system; and though they may be killed in and banished from the blood, some still remain. Further, after a period of dosage, the trypanosomes which have not been killed, or some of them, begin to acquire a resistance to the arsenical drug; and when they have acquired this immunity against the poison we can no longer arrest their development in and ultimate destruction of the patient's body.



THE LARVA OF *STEGOMYIA CALOPUS*

What we need, above all, is therefore the radical method of destroying the insect species without which the disease cannot spread. This is now being done by all the nations which possess Central African colonies. Where men are face to face with great and dangerous facts which are novel and must be mastered, they waste no time in argument, but act, just as we should act in this country if tuberculosis had been unknown last year and were killing us at the rate of ninety thousand a year now.

But flies of one kind and another are very common. May they not be responsible for other diseases besides those which the tsetse-fly conveys to man and various lower animals? Something has already been said of malaria in India. Let us now consider the plague which has raged there in many epidemics for some years past, having found its way south from its ancient endemic home in China It has been known for many years that



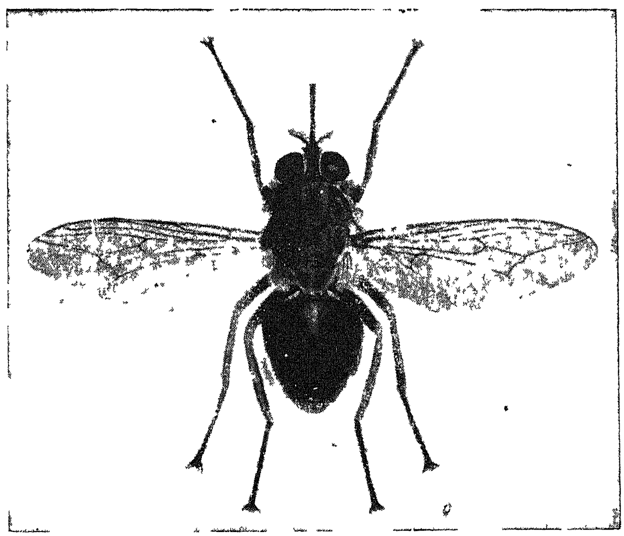
STEGOMYIA CALOPUS, THE CARRIER OF YELLOW FEVER

Oriental plague, bubonic plague, the "Black Death" of history, is due to a bacillus, *Bacillus pestis*, against which all drugs hitherto tried have been unavailing. This is the disease which has in the past visited the British Isles, as in the Plague of London, and which has paid frequent visits to them since, always to be arrested at or near the port of entry. As far back as the time of the Boer War observant doctors were talking about the fly as the conveyer of typhoid; and in 1906 a plague commission, sent afresh to India, and having the new knowledge discovered by Manson and Ross and Bruce in its head, began to look for an insect as the carrier of the plague bacillus. They found the insect, in the shape not of a fly, but of a flea, and especially the rat-flea We are definitely to discriminate between this and previous cases, for a bacillus has no such complicated life-cycle as the parasites we have lately discussed, and needs no intermediate host, as they do Thus a bacillary disease may be communicated in many ways; and plague, for instance, when it attacks the lungs — the deadly "pneumonic plague" seen in Manchuria — is conveyed by the sputum, like tuberculosis or influenza.

The chief agent in the conveyance of this disease — which does not usually affect the lungs and so cannot be spread by the sputum — has been found to be the rat-flea. This insect bites both man and the rat. When it bites a man who suffers from plague, the bacilli thrive in the flea, and may be passed by it into the blood of another man or of a rat Or the rats may be the first sufferers, and then the flea conveys the bacilli from them to man. Epidemics of plague among rats often precede those in man, and dead and sick rats have for long ages been suspected in countries where plague is common. Other animals besides rats may sometimes be affected. In California the ground squirrel (*Clitellus bucheyi*) has become infected and may spread plague through its fleas. But the rat, both the blockhouse and the brown sewer or Norway rat, are the great enemies of man in regard to this disease and a relentless war of extermination of these rodents will be our greatest safeguard against this awful disease. Already the sanitary authorities at many ports, especially in regard to ships coming from countries where plague exists, take steps to destroy the rats on such ships, or to prevent them from coming ashore. The increasing stream and variety of commerce, drawing the world closer together, is also making it far easier than in the past for diseases like plague to be spread and sown afar.

If plague had as often been brought to the great commercial centers two centuries ago as it is nowadays, our ancestors would scarcely have escaped But now, when it reaches London or Liverpool, New York or San Francisco, it scarcely gets any further, because exact knowledge, applied to the problem, bars the way.

In India the plague is formidable and tragic. European science and humanity have not been entirely idle Methods of prevention and treatment, dependent upon the preparation of special substances from the bacillus itself, have often proved useful, even on a large scale But before diseases of this type can be eradicated India will have to have something like the system of primary sanitation which we have here. That time is still incalculably distant, but meanwhile the knowledge regarding the flea and the rat can be applied in some degree, and the spread of epidemics can thus, at any rate, be checked.



THE TSETSE FLY, *GLOSSINA PALPALIS*, THAT CARRIES THE TRYPANOSOMES OF SLEEPING SICKNESS

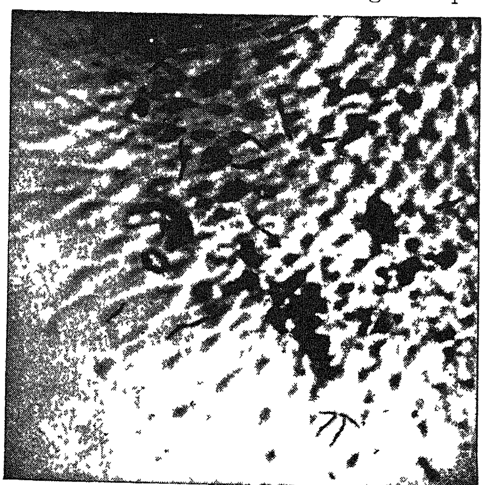
But we have not yet done with biting insects, nor with the animal parasites they convey. Once widely spread over the temperate and tropic zones was a disease called "relapsing fever", now confined to districts where there is much overcrowding and dirt. Since 1873 it has been known to be due to a spiral-shaped organism, a kind of animal parasite not unlike the "spirochæte" of syphilis to which its discoverer, Obermeier, a German, gave the name *Spirochæta recurrentis*. In the United States some observers had shown that Texas cattle-fever, or "red-water fever", is propagated by the bites of ticks. In 1904, two sets of investigators proved, in Africa, that relapsing fever is distributed by the bite of a special tick, and now we call the disease tick-fever. Drs. Dutton and Todd went on to show that the spirochæte can pass from the infected tick to its eggs, so that the larval ticks which hatch from them become infected, and a kind of epidemic is produced among the ticks, which can subsequently infect man. Pasteur, many years before, had shown that the same thing happens with the parasite of silkworm disease; the infected moth transmits it to her eggs, and so the disease proceeds It was while working out the same facts in respect to the parasite of relapsing fever that Dr Dutton became infected with the parasite, and died of the disease.

Having got so far with fleas and ticks, we begin to guess that there is even more to be found What about the cockroaches, beetles, lice, etc.? May not diphtheria, scarlet fever, typhoid, typhus and many more similarly be conveyed by insects? Must we not suspect vermin of all sorts?

The domestic fly, *Musca domestica*, does not bite. We have always had it with us, and we regard it as a necessary nuisance. But after what we have learned about mosquitoes, tsetse-flies and fleas we require to study the fly more closely. It is now known that the fly conveys disease. Dr. Beauperthuy guessed the truth of this long ago. Dr. L. O. Howard, when he was Chief of the Bureau of Entomology, of the U. S. Department of Agriculture, called the ordinary domestic house-fly the "typhoid fly", and the only objection to the name is that the fly conveys too many other diseases for it to be adequate.

He says: "As the water-barrel is to the larvæ of the stegomyia, and the earth-pool to the larvæ of the anophelines, so is putrid, fermenting material to the larvæ or maggots of the fly" Where the fly is, filth is not far behind — in the dustbin, or the stable-yard, or the manure in the garden soil round the house

The fly does not act as an "intermediate host" for animal parasites, but conveys the humbler and simpler bacteria which need no such convenience for their life-cycle It has been experimentally proved to convey cholera and typhoid and tuberculosis, to which "summer diarrhœa" and the cruel ophthalmia of Egypt must be added As the disease-breeding mosquitoes must go, and have gone from the Canal Zone, so the common house-fly must leave our towns. The protection of our dwellings by the use of screened windows and doors is not sufficient. Relentless war must be waged on the insect itself in the effort to exterminate the pest. Anyone who realizes *in what* the feet of the fly have just been that are now upon his sugar-bowl or in his milk, is more likely to leave the room at once, and urgently, than to laugh Anyone who, under a lens, has seen the fly vomiting into his food the nameless contents of its stomach will scarcely trouble to inquire whether those contents actually include "pathogenic organisms".



PART OF A FLY'S FOOT SHOWING BACTERIA ADHERING TO IT

Here we transcribe the excellent directions now in official use in New York They are worthy of imitation everywhere. and furnish appropriate comment on certain practices, all too common, at which the next generation will marvel, wondering whether we really called ourselves civilized

Keep the flies away from the sick, especially those ill with contagious diseases. Kill every fly that strays into the sick-room His body is covered with disease-germs.

Do not allow decaying material of any sort to accumulate on or near your premises

All refuse which tends in any way to fermentation, such as bedding, straw, paper waste and vegetable matter, should be disposed of or covered with lime or kerosene oil.

Screen all food.

Keep all receptacles for garbage carefully covered, and the cans cleaned or sprinkled with oil or lime.

Keep all stable manure in vault or pit, screened, or sprinkled with lime, oil or other cheap preparation.

Cover food after a meal; burn or bury all table refuse.

Screen all food exposed for sale.

Screen all windows and doors, especially the kitchen and dining-room.

Don't forget, if you see flies, their breeding-place is in near-by filth. It may be behind the door, under the table or in the cuspidor.

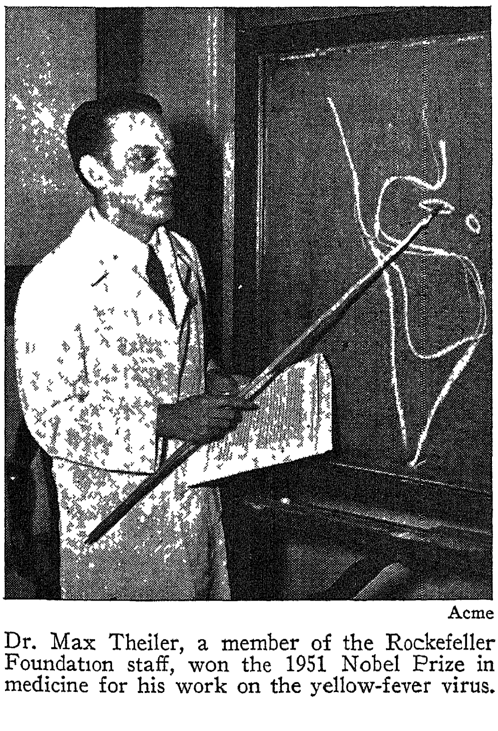
If there is no dirt and filth, there will be no flies.

If there is a nuisance in the neighborhood, write at once to the Health Department.

So much, at present, for the question of man versus insects, though we may be forced to return to it. Even now investigations are proceeding which will greatly extend our knowledge, and make this subject appear more important than ever. But one or two other diseases must be mentioned here, because they likewise depend upon a struggle, now on one side a conscious struggle, between man, with his intelligence, and low forms of animal

or vegetable life. Among the most dreaded of these organisms are the hookworms Two species of hookworms — *Ancylostoma duodenale* and *Necator americanus* — attack man; they cause the disease known as ancylostomiasis, or hookworm disease. This disease is widespread; it is especially prevalent in the southeastern part of the United States, the West Indies, Central America, much of South America, the Nile Valley, West and Central Africa, many parts of eastern Asia and many islands of the South Pacific.

The hookworm attacks the mucous lining of the small intestine; it sucks blood and destroys tissues. The eggs of this parasite do not hatch inside the body. They pass out with the feces of the sufferer and hatch when they reach a medium — generally the soil — that is sufficiently warm and moist. Hookworms enter the body in several ways. In certain cases they are swallowed with either food or water that has been contaminated; in due course they reach the intestine and fasten upon its lining. Generally, however, they enter the body by burrowing through the skin, particularly the skin of the bare feet. They penetrate the blood vessels and are carried to the lungs. Like any other foreign substances in the lungs, they are brought up to the throat. They are then swallowed



Acme

Dr. Max Theiler, a member of the Rockefeller Foundation staff, won the 1951 Nobel Prize in medicine for his work on the yellow-fever virus.

The hookworms produce an itching sensation at the places when they enter the skin In the lungs they may open up passageways for dangerous bacteria After the hookworms have established themselves in the intestine, they may cause great discomfort The damaging effects depend upon the number of hookworms to be found in the intestine of the sufferer. An infection of, say, 50 worms seldom produces definite symptoms; but a 500-worm infection is a serious matter. It has been estimated that more than half a pint of blood a day may be sucked from the capillaries by 500 hookworms. A good deal of the iron contained in the red corpuscles of the blood is lost in this way, and the sufferer develops anemia. In a severe infection, the patient is pale, lazy and indifferent; he becomes breathless after the slightest exertion; his pulse is weak.

The treatment of hookworm disease

The treatment of hookworm disease consists of expelling the worms. Thymol, oil of chenopodium and carbon tetrachloride have all been used in the past for this purpose; at present tetrachlorethylene is generally employed. The patient is required to adopt a diet rich in iron, proteins and vitamins in order to hasten his recovery.

Malta fever, or Mediterranean fever

For ages man has been cursed with the disease called Malta fever, or Mediterranean fever. It infests the islands and the shores of the Mediterranean and is also found in India, China, North and South America, the West Indies, South Africa and other parts of the world. In 1887, David Bruce, whose work on sleeping sickness we have already discussed, discovered the parasite of the disease, a very small bacterium known as *Micrococcus melitensis.* But for many years the mode of infection could not be traced, and little or nothing could be done for the patients.

In 1905, 403 British officers and men were invalided home from the garrison in Malta, owing to this fever, after an average stay of ninety days in hospital there. Well knowing the distribution of the tubercle bacillus in the cow, Bruce returned to the disease which he had studied many years before, and looked for his micrococcus in the goats which yield the milk consumed in Malta. He found that half the goats of the island, though healthy, contained the parasite, and in 10 per cent of them the milk contained the micrococcus. Here, then, were "healthy reservoirs" of the parasite, like the healthy human reservoirs of malaria.

In June, 1906, the campaign against the disease began. Goats' milk was banished from the hospitals and regiments. In the third quarter of 1905 there were 258 cases; of 1906, only 26. For some time the native and civilian population could not be persuaded to follow the advice of science; but the soldiers and sailors had to obey orders, and the disease vanished from among them. In the naval hospital in Malta, practically every patient suffered from the disease, but after stopping the supply of goats' milk there were no more cases.

No disease known to man has a more sinister fame than leprosy. Literature has acquainted us with it — many Biblical passages, and R. L. Stevenson's tribute to Father Damien, who contracted the disease while working for those "butt-ends of men" the lepers among whom he died. Many years have passed since 1879 when Dr. G. A. Hansen, of Copenhagen, discovered the "lepra bacillus", which is now known to cause the disease. Chaulmoogra oil has been reported as effecting at least some cures.

From time immemorial the disease has been looked upon as contagious, but it is certainly not highly contagious. What seems possible is that some insect — yet again an insect — may convey the disease from one person to another. Dr. Beauperthuy suspected certain insect vermin and also the house-fly. The facts may soon be made clear; and meanwhile the suggested parallel between this ancient scourge of mankind and many another is worthy of note. For in this disease also we have to recognize a struggle between two forms of life, the highest and one of the lowest we know; and it is quite possible that a third form of life may also play an essential part, and so add to the reasons why man must henceforth range his species as a whole against all insects whatever that prey upon his person, his products, his food or any of his personal belongings.

In 1883 the dread malady Asiatic cholera was proved by Koch to be due to a microbe, of curved form, *Spirillum choleræ asiaticæ*, often called the "comma bacillus". The same measures which prevail against other bacillary diseases prevail in this case also. Probably no third species is involved in the case of this disease, with the exception of the fly, as a purely mechanical carrier. Our grasp of this disease in its relation to the evolution of man is weakened by its remoteness. We need only turn our eyes to our own cities, in summer, and there we find a deadly disease, killing our infants like flies, which is known as "cholera infantum". Many years of search have left us still uncertain as to the parasite of this disease; as in the case of smallpox, scarlet fever, etc., we cannot definitely point to any living form, and say that causes the disease. We kill the mosquito that transmits the infection and yellow fever vanishes. So here, though we are not possessed of the crucial evidence which was acquired in Havana, we can say with practical certainty that the house-fly plays a not dissimilar part to the stegomyia, only that the unknown parasite of cholera infantum is apparently simpler than the known parasite of yellow fever, and requires no "intermediate host" for the development of its life-cycle. Thus, the fly is not *essential* as the mosquito is, but its importance is great and its abolition would probably save some scores of thousands of infants in this country every year. Such, in outline, are the vital relations between the lives of insects and the life of man, as science has thus far unraveled them.

THE COMPANY OF LIZARDS

Small-Brained Survivals from Very Early Ages That are now Again Multiplying on the Earth

UGLY BUT QUAINT, STOLID BUT QUICK

LIZARDS have a future, it is said. They are, remarks a high authority, apparently on the increase in number and species, but certainly not in size. Our authority views, perhaps, possibilities rather than probabilities. There would be a future for many forms of animal life were it not that they need conditions incompatible with the prosperity and progress of the human race. Eighteen hundred species of lizards are scattered over the earth, and there is one in the sea. We have lizards which "fly"; which, with adhesive feet, scale vertical walls; and we have lizards with no limbs at all; lizards with tails so fragile that, at the will of their owners, they snap like the limbs of the sea-dwelling brittle-star; lizards that are among the most baleful-looking of living creatures, yet are harmless; lizards which seem innocuous, yet are deadly in their attacks. But throughout the great group there is not a brain worth mentioning. Instinctive adaptability there is in abundance, and very remarkable examples of it, too.

The African chameleon, with his kaleidoscopic change of hues amid the trees, cannot hope to thrive as the advance of civilization makes his trees more rare. He will disappear as the tuatera, or sphenodon, is disappearing. Geckos may make merry in oriental houses for the time being, but there is hardly space or freedom enough for a new type of material modification to evolve. Time and space are against the group, or, at any rate, against such genera as have their homes within hail of the lands into which civilization is daily thrusting.

The deserts remain, and the waters. It will be there, if anywhere, that the future of the lizards must lie. And even the deserts may be reclaimed for man.

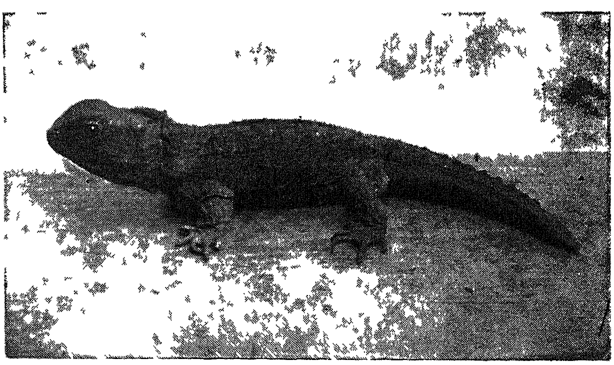
The whole brigade today, whatever the time to come may hold, is a very interesting one. There lives a lizard-like reptile which, though it cannot be considered as the ancestral form of the lizards, is undoubtedly descended from the great group of reptiles from which existing forms arose. This astonishing relic of the past — the sphenodon, or tuatera — has persisted since Permian days, the most primitive reptile on earth. As has been shown in our third chapter of this group, it is now rapidly vanishing before the advance of man. The sphenodon has stood still, so to speak, for millions of years; crocodiles, flying dragons, heloderms and amphisbænas tell the tale of progress.

The tuatera is the sole existing representative of the "beaked lizards", yet is not a lizard. Neither, for that matter, is a chameleon a lizard, but reference to both may be legitimately included in this chapter. As the tuatera has affinities with the birds no less than with tortoises, so the chameleon, unlike all other lizard-like forms, has one point in common with a certain type of birds — climbers, and birds of the parrot tribe. Named indifferently the worm-tongued and the four-handed lizard, this creature's resemblance to the parrots is indicated in the latter term.

The toes are divided into opposing branches. In the forefoot three toes are grouped to form the inner branch, and two form the outer; but in the hind limbs the

order is reversed This division of the toes gives the reptile a unique gripping power, and even the most casual observer is struck by the perfection of this modification Another extraordinary feature of the chameleon is its eye This is one of the most remarkable organs exhibited by any terrestrial animal The pineal eye, best developed in the tuatera, which may have enabled ancient reptiles to see out of the top of the head, could have possessed no greater advantage than that afforded by the chameleon's organs of vision Here we have large and protuberant eyes covered by thick granular lids perforated only by minute apertures for the pupils. The two eyes can be moved independently of one another One can look straight ahead, while the other looks backward or up. Why this doubling of the field of vision should accompany such excessively minute openings to the lids is a mystery

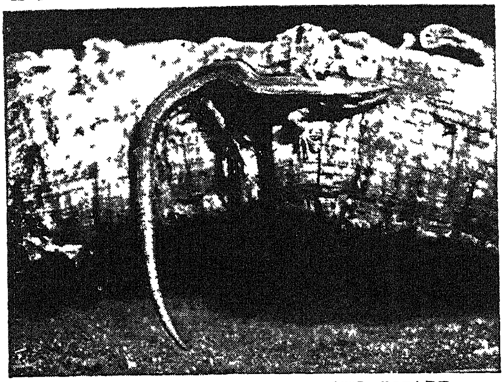
So seemingly utterly lethargic a creature needs all the aids that can be afforded, for it is apparently the very embodiment of sloth and deliberation There can be no doubt that its slowness to avail itself of food, coupled, of course, with its power to undergo prolonged fasts, deceived impatient observers among the old naturalists into the belief, not yet extinct, that chameleons exist on air. From Shakespeare to Shelley, all writers were wrong on this point As a fact, of course, the reptile captures its insect prey by one of the most remarkable tongues that can be imagined When shot forth to reach a fly or beetle, it measures from seven to eight inches, and expands at the extremity into two parallel transverse flaps, coated with a gummy fluid by which the insect is secured The extrusion and withdrawal of the tongue are so rapidly achieved that the human eye cannot follow the movements, and has to call the camera to its aid.



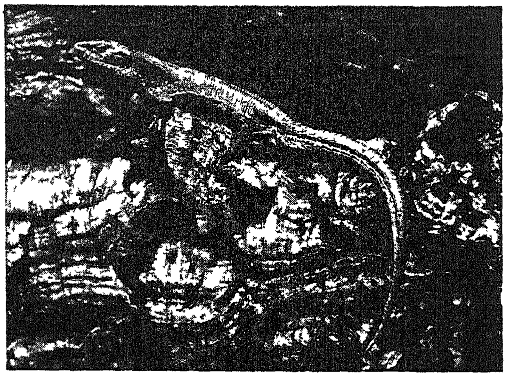
THE TUATERA, OR SPHENODON

This peculiarity as to the tongue does not, however, very sharply separate the chameleon from other lowly types of life A man need not travel farther than his own garden to see a very perfect extrusible tongue at work, *i e* that of the common toad, though this works on a slightly different mechanical principle Even the rapid flushing of changeful color in the chameleon of our Southern States is not a unique feature, though it is better developed in this species than in any other form. Among lizards proper, the same peculiarity is observable in a lesser degree in the changeable lizards (*Calotes versicolor*), and, to a smaller extent, in Blandford's lizard

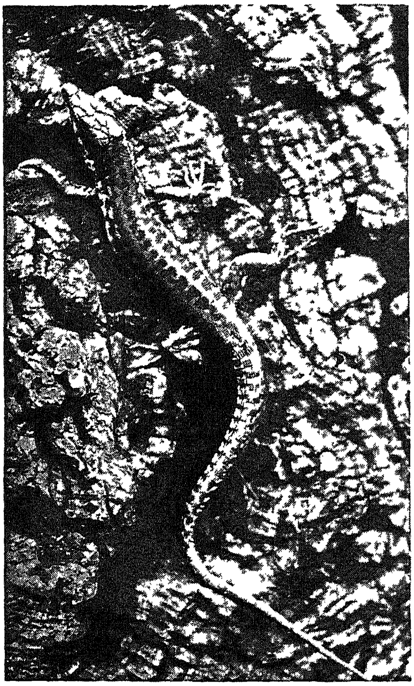
The great group of geckos, numbering over three hundred species, and widely distributed throughout the warmer parts of the globe, are a good example of the great diversity of habit and equipment by which the lizards are distinguished. The feet of the majority of them are equipped with adhesive discs, by means of which the little reptiles run up a wall or a window-pane, and scamper, head downward, from a ceiling with the celerity and certainty of a fly. These are the species common in human habitations. Others restrict themselves to deserts, and in these many species lack the discs on the feet. Some live among the rocks, some haunt bushes and low trees. One, the most remarkable of all, has developed the parachute resembling that of other so-called "flying" animals with which we have already dealt. The bark gecko, a lizard nine or ten inches in length, dwells on the lichen-covered bark of trees, and so closely resembles its background as to stand for one of the most famous examples of protective coloration. Interest centers, however, chiefly in the species which have become parasitic in the homes of man.



THE COMMON OR VIVIPAROUS LIZARD

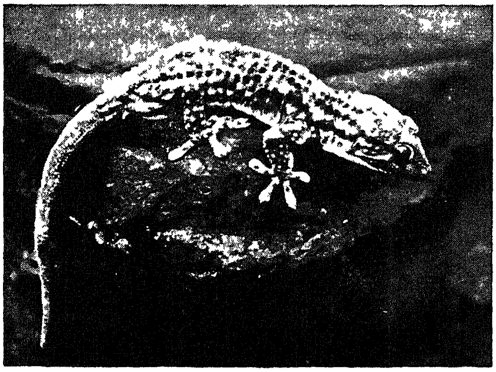


THE SAND, OR AGILE, LIZARD

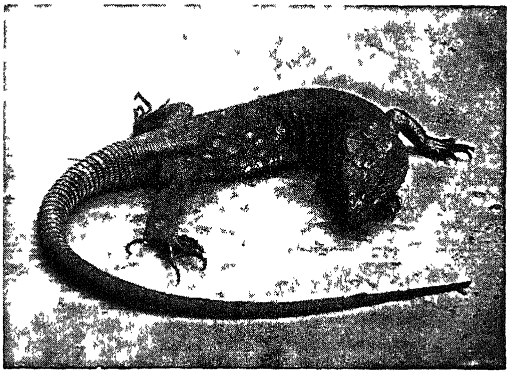


THE WALL LIZARD

A PAIR OF GREEN LIZARDS



THE WALL GECKO

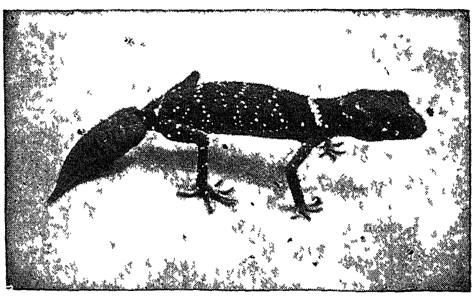


THE EYED LIZARD

To the white man the gecko is not wholly unwelcome, for it is a great snapper-up of insects. Anatomically it possesses distinct claims to notice, for the modification of the toes by which it makes its dazzling journeys across the ceiling is a means to progress of a remarkable kind. Household geckos are not confined to one species, and

THE CHAMELEON

various differences are to be noted in the feet of each. In some species the claws are withdrawn into sheaths at the extremities of the toes, while in others the claws emerge from the plates of the discs themselves Another species, such as the lobe-footed, may possess no claws at all, while, again, others have the toes webbed as if for swimming, an art to which no gecko ever willingly inclines. Long as the geckos have haunted human dwellings, they



THE NAKED-TOED LIZARD

have never ceased to be viewed with superstitious horror by their unwilling native hosts, who regard the creature as venomous, as "the father of leprosy", and so powerful as to be able to injure a bar of solid steel with their teeth. Needless to say, this lizard is absolutely harmless and free from guile.

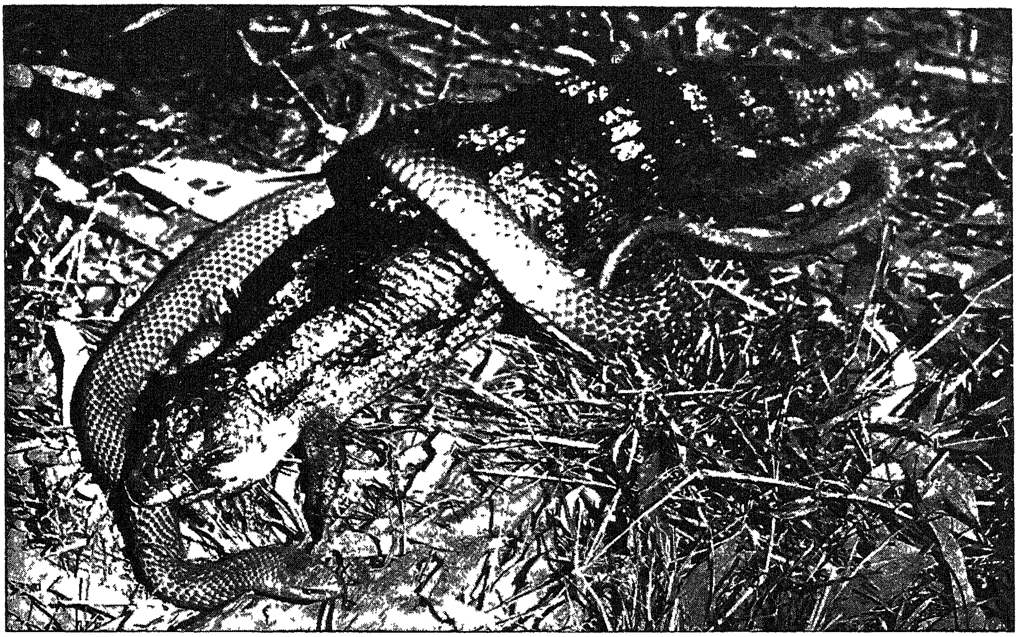
A second great family (numbering over 200 species) contains the agama lizards, in which are grouped some of the most striking forms of lizard life. First of these are the flying dragons, as neat little creatures as ever bore a repellent title. About 20 species of "flying dragons" are found in the Indo-Malayan countries At first sight the careless observer might think that it needs but an extension of the wing-like membrane to the legs and tail to furnish these little reptiles with true organs of flight resembling those of the bat But a moment's examination shows how different is the plan before us. The bat has converted his hands into wings; here, however, it is the ribs that furnish support for the flight membrane. The last half-dozen or so of ribs are continued through and beyond the skin of the body, and are webbed together by a membrane which, when expanded, is one of the most effective parachutes. Ribs and membrane fold down snugly like a fan when the lizard is at rest.

Endowed with this extra aid to flight, the small lizard, hiding amid the tree-tops. launches itself with confidence and accuracy into the air in pursuit of insects, and in the same manner passes with rapidity from tree to tree, illustrating before our eyes, as we think, the manner in which true flight originated. Our little dragon, so called, with the crocodile as the "highest yet" of the reptiles, with the chameleon as the most specialized in another direction, and with the tuatera to mark an approximate starting-point, constitutes as interesting and suggestive a group as can well be found.

The typical agamas are to be found on the borders of southeastern Europe, throughout the greater part of southeastern Asia, and in the whole of Africa, but while they abound in the Punjab, Sind and the Himalaya, they do not appear in India proper. One of the forty species, the agile agama, is distinguished for the speed of its movements, but none of them is slothful; and though they are to be found in large numbers in favorable positions, basking in the sun or hotly pursuing insect prey, so alert are they that

their capture is a matter of considerable difficulty. Protective coloration is noticeable in many of the species, but they all appear to have inherited a notion that swiftness of departure is the safest course.

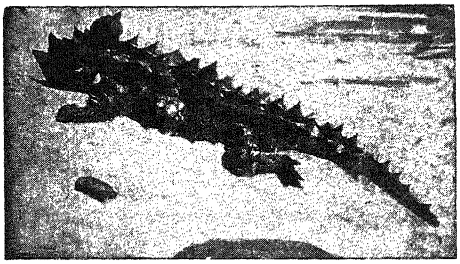
Another highly specialized agama is the Australian frilled lizard. Here, again, we have a phenomenal development of external membrane, but this springs not from the ribs, but from the covering of the neck and throat, and is supported by rods of cartilage, and opened and closed by special muscles The purpose of this remarkable feature is, of course, not flight It is simply a sort of mask — a mask which screens almost the entire body from view, and raised obviously as a menace to enemies. With his frill up and his jaws wide open, this lizard is truly a formidable-looking little reptile, but he is perfectly harmless for all his terrifying show, and is only too thankful, when the danger is past, to rear himself upon his hind legs and waddle away with the gait of a bow-legged acrobat on a very treacherous tightrope. Another great impostor is the moloch, also an Australian product. The menacing attitude of the frilled lizard seems to declare, "I could if I would", but the appearance of the moloch boldly suggests "I can and I will" *Moloch horridus* is that redoubtable-looking lizard which the settlers have named the "thorny devil". Beginning at the head, which has an armament of curving horns and spines, the creature is positively crowded to the very tip of its tail with spines and bosses and defensive tubercles, a nightmare of protective harness Australia was unknown to the early writers of natural history, or to what appalling legends would this really inoffensive pretender have given rise! It is simply a harmless ant-eater, which adds a modicum of vegetable matter to its modest diet, and the whole armor, from which it gets its forbidding scientific name, is simply a relic of the long ago.



A FIGHT BETWEEN THE BLUE-TONGUED LIZARD AND THE BROWN SNAKE OF AUSTRALIA

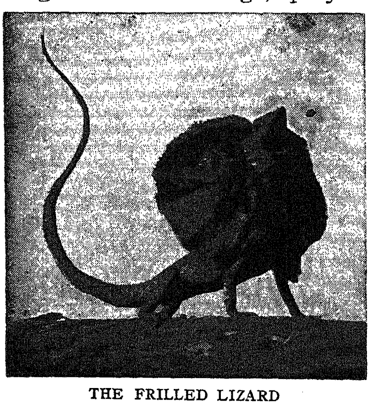
The iguanas take, in the New World, the place of the agamas in the Old. They do more than that; for while practically every group of agamas has its duplicate in groups of iguanas, there are other groups of iguanas which have no parallel among the Old World brigade. It should be added that two genera of iguanas occur in Madagascar, a puzzling instance of discontinuous distribution, which is explained by the discovery of fossil iguanas in the upper Eocene deposits of France, where agamas seem never to have appeared.

Many of the iguanas possess the power of more or less altering their hues. Our American chameleon is a member of this interesting family. Some of them are as gorgeously colored as butterflies, yet they contrive so wonderfully to blend their colors with the tone-scheme of their surroundings that only the brilliant yellow of the eyes betrays them, until they leap,



THE MOLOCH

with a cat-like spring, upon their insect quarry. The iguanas are represented in the United States by two species which occur in our southern states. Other species are found in South America, Central America, Mexico and the West Indies. These are large, powerful creatures, some of them reaching the length of six feet. In our southern species the tail is covered with rings or whorls of large, spiny scales,



THE FRILLED LIZARD

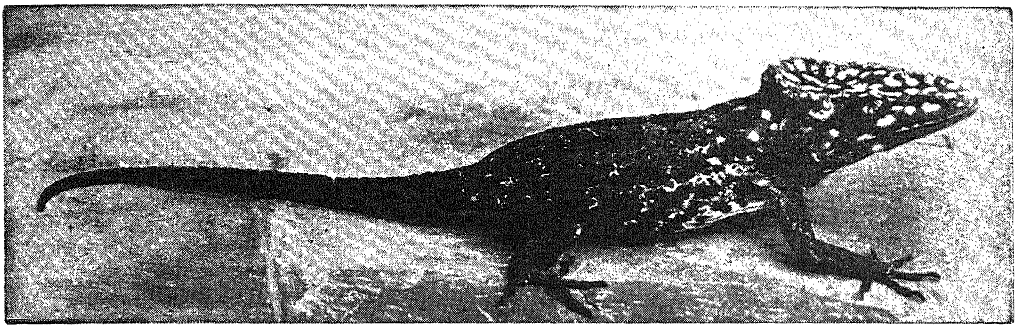
and can be switched back and forth with lightning-like rapidity and surprising force, dealing really formidable blows. The feet are provided with long toes and stout claws, and the creatures are agile climbers.

The far-famed basilisk is an iguana.

> . . . Whose pestilential breath
> Doth pierce firm marble, and whose baneful eye
> Wounds with a glance so that the soundest die.

Many of our ancient naturalists imagined another creature of the same name, but there can be no doubt that the bizarre appearance of the genuine lizard must have been a starting-point for many of the later legends that grew up about the harmless creature, which a child might handle with perfect safety. That is to say, the ancients imagined a fearsome beast which never existed in earth or sea; and the first man who knew the story, upon seeing this fantastic wonder of the New World, concluded that this must be the veritable basilisk, or cockatrice, of hideous reputation. But how its character for blasting with its breath the heath and all upon it could be reconciled with the luxuriant vegetation and ample population of tropical Central America, in which basilisks flourish, the early naturalists probably did not stop to consider. As a fact, the basilisk is essentially a very ordinary lizard, endowed with a frill to his tail no more alarming than that of the frilled newt, and a similar membranous expansion covering the back, suggesting a reptile with the fin of a fish grafted upon it. The head, too, is peculiar in that from its rear springs a cartilaginous lobe. This lizard is entirely herbivorous, and, so far from seeking to inflict injury upon a living creature, it has no thought, upon discovery, but of flight. Its escape is effected, as a rule, by plunging into the water from an overhanging tree, which is its favorite place of rest.

The Galapagos Islands possess two very interesting genera of iguanas, one terrestrial, the other marine. The former is a large reptile, sluggish, feeding on the leaves of a succulent cactus and the foliage of low-branching acacia, and making its home in burrows excavated in loose soil lying between fragments of lava, or, more commonly, in the soft sandstone-like tufa. The marine genus comprises still larger lizards, the greatest measuring as much as $4\frac{1}{2}$ feet. They must have taken comparatively recently to life in the sea, for they go to it only for food, seaweed, and come ashore at the first suggestion of danger. The curious thing is that, when menaced on land, they do not take to the sea; when they can no longer run on land,

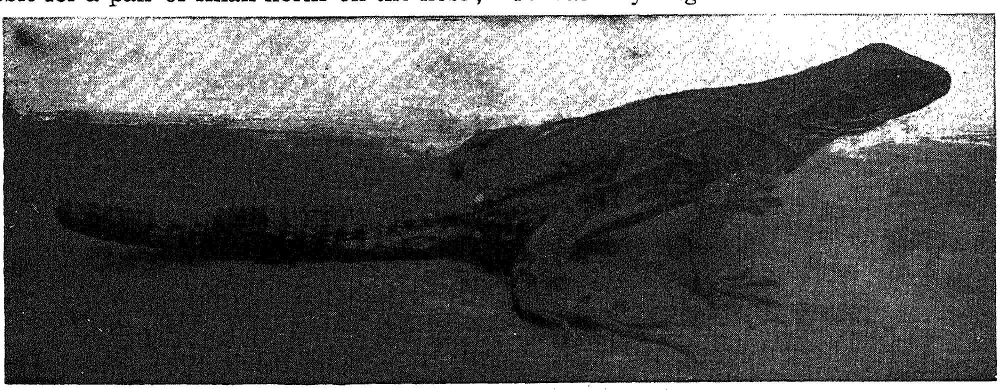


THE ANOLIS IGUANA

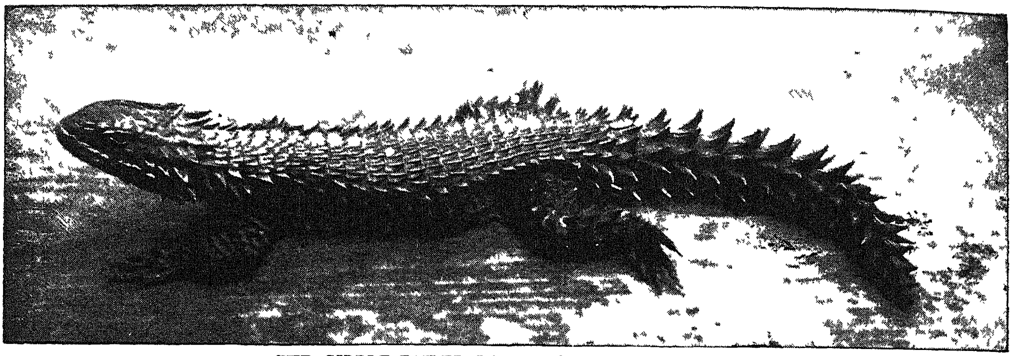
they halt at the edge of the water; and if thrown out to sea again and again, they immediately return each time to land. They have no natural enemies on terra firma, so they do not associate the thought of danger with life on dry land. Sharks, haunting inshore waters, are their chief cause of alarm, and they seek safety beyond the range of these monsters. When, therefore, a man, unrecognized till then as hostile, plays upon their fears, they cannot adapt themselves to the new situation, but cower down on shore, whither instinct impels them to resort whenever peril draws near.

THE BASILISK

Among other notable iguanas must be mentioned the rhinoceros iguana, remarkable for a pair of small horns on the nose; and the horned iguanas, commonly, but wrongly, termed the "horned toad" of California. Here, again, a most impressive armament of spines has been developed, but the lizard is innocent of any attempt at aggression towards anything but the slow-moving insects of the barren sandy wastes in which it dwells. Of late, however, it has come prominently into notice by reason of an unsuspected method of defense, by means of which it can at will eject jets of a fluid resembling blood from the eyes or from glands thereabouts which have not yet been located. For years a tradition to this effect existed, but hundreds of specimens were handled in vain by eager naturalists.



THE SPINY-TAILED IGUANA



THE GIRDLE-TAILED LIZARD OF SOUTH AFRICA

This is one of the strangest of defensive effects There are many such, of course. The llama and certain African snakes spit: many sea-birds eject a malodorous, oily fluid from their nostrils; the sea-lizard squirts a bead of fluid from each nostril; skunks and other animals secrete intolerable fluids; the bombardier beetle and certain caterpillars are proficient marksmen, with batteries charged with acid secretions. But the defensive action of the horned lizard is surely the most striking of all There is no suggestion that physical ill results to the recipient, but the action is so unexpected, and the method of effecting it so astonishing, that the net result must be calculated as facilitating the probable escape of the lizard And yet the latter is so well armed externally that such defense ought not to be necessary. Here, perhaps, is the rudiment of a new plan of campaign evolved as an adjunct to armor, which in course of time might be so developed as to render the cumbersome coat of mail unnecessary That is the sort of thing a naturalist, given a million or so of years, would have the joy of watching

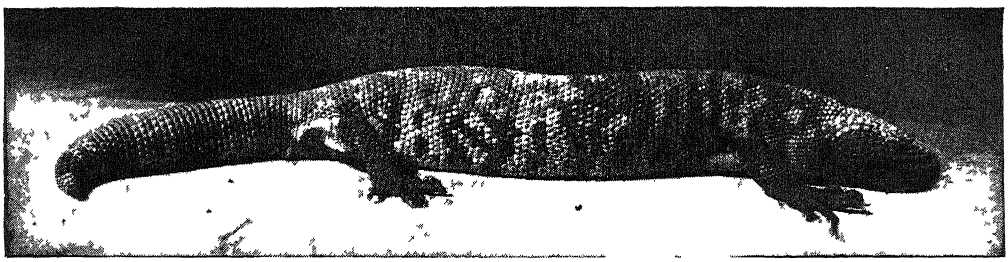
HORNED IGUANAS

Mention was made in the preceding chapter of certain lizards which resemble snakes, and here we may note one or two of these singular genera The elongated cylindrical body and absence of feet might be thought a sufficient modification to admit of the whole being grouped in one genus. That, however, is not the case

THE LAND IGUANA OF THE GALAPAGOS ISLANDS

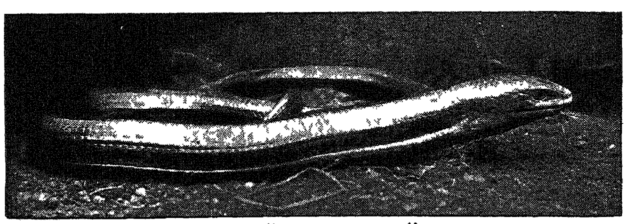
Just as we find venomous snakes evolved from varying families of non-venomous reptiles, so we find quite independent parallel development in the lizards tending to one end in several distinct genera In the scale-footed lizards of Australia and New Guinea the fore limbs have entirely disappeared, while the hind pair are now merely vestigial, barely perceptible in the female, scale-covered and functionless in the male, which is a reptile twenty inches in length The girdle-tailed lizards include a South African genus, *Chamæsaura*, in which the fore limbs are missing, while the remainder are four-limbed and active climbers Resembling


THE SLOW-WORM

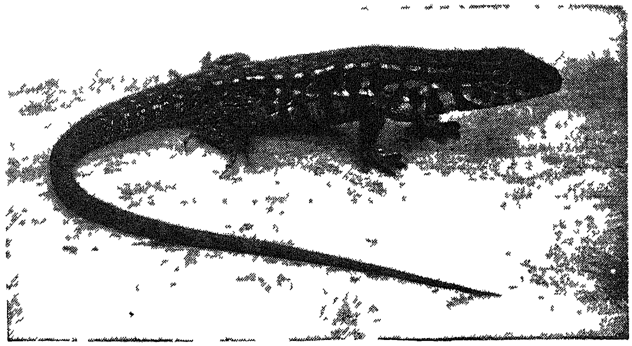

THE POISONOUS ARIZONA LIZARD, GILA MONSTER

in many respects the iguanas, the scale-tailed lizards are more nearly related to the slow-worms than are the scale-foots

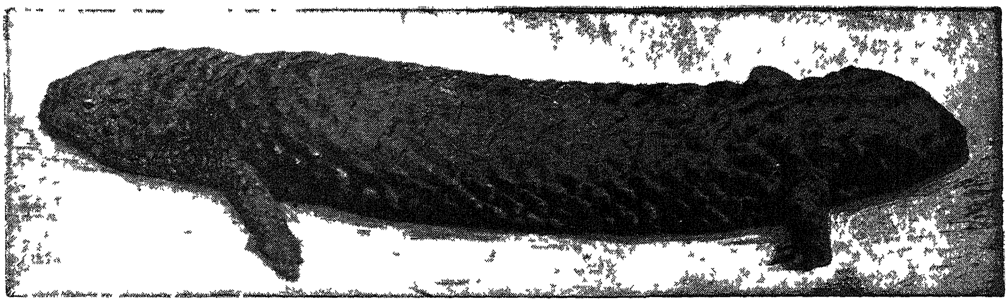
There is no more absurd name in the whole range of nomenclature than that of "slow-worm", or "blind-worm", applied to the *Anguidæ*. They possess excellent sight, as the merest peep at their bright little eyes suggests They are far from slow, but as active as any snakes of their size The four limbs are entirely absent, so far as external sign is evidence, and they slough their skins whole in the manner common to all snakes Some of the genera retain their limbs, some lay eggs, some produce their young alive. The scheltopusiks, or glass-snakes, first thought to be limited to the wooded valleys of the steppes bordering the Volga, but now found to extend to other parts of Russia, to Hungary, Istria, Dalmatia, Asia Minor, Syria, Persia, Turkestan, Morocco and even to northeastern India, Burma and North America, serve to remind us how much the modern naturalist has had to learn to correct the fallacious teaching of even recent times Like the slow-worm, it is commonly mistaken for a snake, and killed, which is a pity, for it is an unqualified friend of man, devouring mice, insects and even vipers The slow-worm, in turn, is equally to be desired in cultivated areas, for its food is entirely carnivorous, mainly slugs, insects and worms The approximation to the serpent form is here as striking as in any of the families already mentioned, but the attributes of the true lizards remain undiminished to the close observer. The eye has movable lids, which is characteristic of the lizard group No matter how snakelike its form, if a reptile possess an eyelid to its name, it is not a snake, though we must be careful to remember that, as some lizards lack eyelids, we must not deem a lidless reptile a four-footed snake! One fact for which the slow-worm is entitled to fame is this: that it was in this


THE "GLASS-SNAKE"

reptile that the pineal eye was first discovered Modern investigations lead to the decision that in the tuatera, at all events, the pineal eye should be read as "pineal eyes" — that there were two of these organs of vision Be that as it may, the one now visible to the left of the median line of the skull is quite functionless, and of the right there remains only the stalk But the discovery of such a method of vision, and all the light that it throws upon the ancient structure and manners of



THE TEJU, OR TEGUEXIN

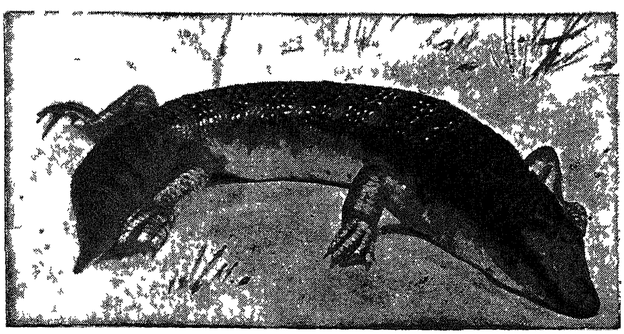


THE STUMP-TAILED LIZARD

gaining a living, we owe to the little slowworm

It is this creature, again, which affords us the best-known illustration of the ability of reptiles to snap and discard the tail. This is the part of the body by which they are most commonly caught, and it is, naturally, of immense advantage to them to be able to cut the cable, as it were, and depart, leaving only a relic in the hands of the would-be captor. The tail can be grown again in a modified form. The vertebræ cannot be renewed, neither can the spinal cord, but a cartilaginous support to a substitute for the original appendage is readily furnished. The "glass-snake", *Ophisaurus*, of the middle and southern United States, also possesses this ability to twist off a considerable portion of its tail, when it finds itself in the hands (or the jaws) of an enemy. An old idea of the powers of this creature accredited to it the ability to regather itself, and continue to live after having been shattered into fragments! Hence the misleading name — misleading in both its parts — "glass-snake".

Another interesting member of the anguid family of lizards is the so-called Gila monster of southern Arizona and New Mexico, a bright-colored black and pink, or orange lizard, of vicious habits, and uncouth, awkward movements. It is our only poisonous lizard.



THE SKINK

The venom is contained in sacs at the base of fangs in the lower jaws, whence it travels by way of a groove in the fangs into the wound in the flesh of its victim. Al-

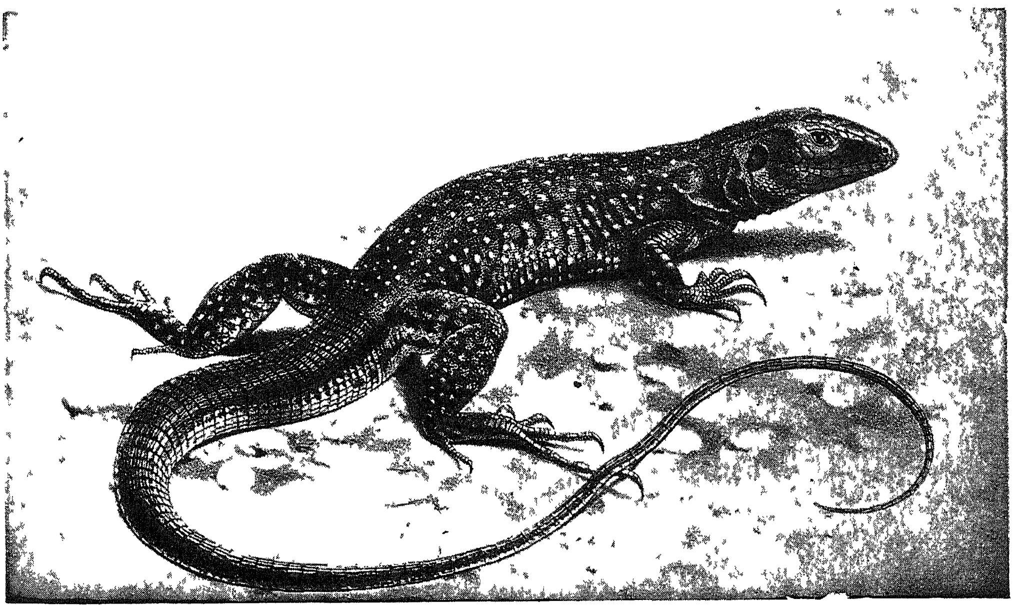
though an attempt has been made to prove that the venom of the Gila monster is not poisonous, the evidence is conclusive that its effects upon small animals are fatal, and decidedly harmful to human beings, though not, so far as is known, lethal

The largest of all the lizards are to be found in the monitors, of which, distributed very generally throughout India, Africa and Australia, there are some thirty living species In the great age of reptiles, India had monitors twice as large as any now existing, while Australia rejoiced in a species measuring fully thirty feet long While some of the species are to be found in deserts, the majority of them frequent well-wooded riversides or marshy ground, in which food and temporary shelter may be had in the waters

The large and powerful tail serves, as it does in the case of the crocodile, as a propeller when the animal is in the water, and as a weapon of offense when on land Entirely carnivorous, the monitors feed upon birds and their eggs, upon lizards, frogs and such small prey, and have rendered the rest of the world good service by their unwearying search for the eggs of crocodiles, so preventing many a fell brood of these dreadful monsters from coming to maturity

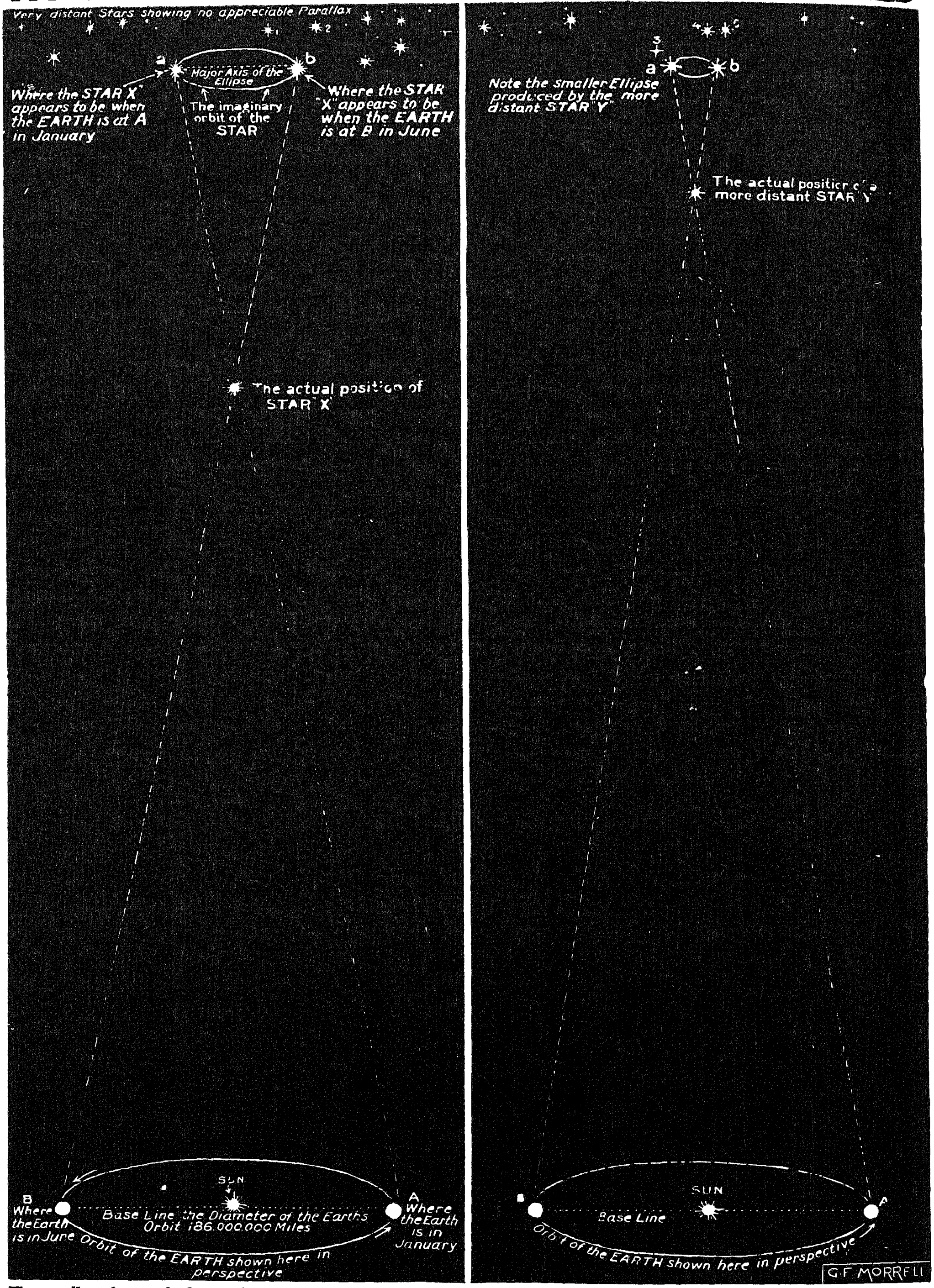
America possesses, in the teju lizards, a group of reptiles which take the place occupied by the typical lizards of the Old World Some of them attain dimensions rivaled only by the largest monitors; some resemble, in the gradual sacrifice of limbs, the amphisbænas These latter are amongst the strangest of the lizard tribe. Many species have retained only the merest vestiges of limbs, while the Mexican representative has lost the hind pair, and retained those in front The peculiarity of these creatures is that they move equally well backwards or forwards, a circumstance correlated with their purely subterranean life The whole family comprises seventeen genera

The great skink family are an extremely numerous host, comprising twenty-five genera and over four hundred species. Singular forms are found in this family, many having squat, plump bodies supported upon tiny and widely separated limbs, while others, remarkable for vivid body-colors, have, for some unknown reason, the tongue brilliantly pigmented. It is believed that two interesting burrowing genera, the *Anelytropidæ* and the *Dibamidæ*, which pass a worm-like existence underground, are simply specialized or degenerate skinks



A LIVELY MOVER FROM BRAZIL, *AMEIVA LEUCOSTIGMA*

HOW DISTANCES OF STARS ARE ASCERTAINED



The parallax of a star is the angular measure of one-half the major axis of the apparent annual orbit which it performs as seen from the earth. Every star has a parallax, but only relatively few parallaxes are measurable; most stars, owing to their great distance, having practically infinitesimal apparent displacements. For instance, in the lefthand diagram the star *X*, when viewed from the earth in June, appears at *b* in relation to the more distant stars 1 and 2, which have practically no parallax, but in January it appears at *a*. The observed value of the major axis of the apparent ellipse performed by the star *X* bears a definite relation to the diameter of the earth's orbit and enables astronomers by mathematical calculation to find out the actual distance of the star from the earth. The righthand diagram shows the smaller parallax of the more distant star *Y*.

A SECRET UNIVERSAL PLAN

The Observations, Calculations and Inferences by which Men Try to Find a Harmony of the Spheres

MOVEMENTS AND DISTANCES OF STARS

IN all its main features, the map of the heavens remains the same throughout the centuries. It becomes more thickly strewn with small celestial objects as these are discovered with improved instruments, but for the ordinary observer who looks at the stars with unaided vision they present virtually the same appearance as they did thousands of years ago to the earliest astronomers The great constellations and the familiar individual stars shine for us exactly as they did for prehistoric man.

Yet the fact is that all the stars are in perpetual motion, and their relations undergo incessant, gradual change. The study of these changes is perhaps the most difficult branch of astronomy. In following the progress of the physical development of stars we have found the history to be full of gaps and uncertainties, but the subject is yielding fruitfully to more and more searching investigation. But the study of the real motions of stars, and of their distances, on which our knowledge of their motions depends, is far more baffling. The difficulty arises chiefly from two causes — the immense actual distances of the stars, and the lack of any fixed reference-points by which to measure their movements. In the latter difficulty we are ourselves implicated in a degree and in modes which are as yet unascertained. Our sun is one star among millions, and, like all the rest, is in constant progress through the heavens, though we are rather limited in our knowledge concerning this progress. For all we know, it may be also implicated with other unrecognized stars as members of a group or system with common motions and in permanent relations No evidence of such relations has as yet been discovered, but that is no proof that they do not exist.

The motion of the earth round the sun and its daily revolution about its own axis, cause an apparent processional movement in the whole universe of stars. The constellations rise and set at different times according to the time of year, and must be looked for in different places according to the hour and season. These apparent motions are familiar to all of us in a general way, and have been actually known and recorded as long as the stars have been studied at all. Their rising and setting and position in the heavens have from time immemorial connected certain of the stars with different primary conditions and labors of human life.

Thus, the ancient Greeks waited until the Pleiades were first seen to climb above the horizon before sunrise, in May, in order to begin their season of navigation, and to them, therefore, the Pleiades were the "sailing" stars; and by many nations the cultivation of the soil was begun in November as soon as the Pleiades were for the last time seen to rise after sunset. The popular use of astronomical terms in defining time and season, by Chaucer and all medieval writers, shows that in the Middle Ages the motions of the stars were not only the interest of special students, but were common and friendly concerns of the people in general. The stars seemed very near to men in those days, and it was taken for granted that in some way, not clearly understood, they were closely linked with human destinies

They moved in space around the earth in wondrous harmonious rhythm, and could be trusted in the guidance of human concerns as no one then would have dreamed of trusting machinery or calendars.

How the Copernican theory upset the old idea of star motions

But the commonly supposed motions of stars were destroyed at one blow by the incontrovertible establishment of the Copernican theory, and our own world was made the sole cause of these profound circlings. Yet modern science is justifying the instincts of the old sages and of all primitive peoples, by discovering new, real and immeasurably vast motions in the stars themselves, individually and in concert. The existence of these motions is beyond doubt. Each star is moving through the heavens with a motion and determination of its own, perhaps shared with others which form with it a partial system among themselves; and it is at least possible that all the stars are united in some still vaster and more magnificent universal scheme of motion. But as to this latter, nothing is actually known so far, and perhaps may never be known.

The proper motions of the stars are by no means easy of ascertainment. In the first place, observation is difficult, because the difference of position as seen by us in the heavens is so extremely minute, even though the actual distance traversed be billions of miles. It is usually recorded in angular measurement, for this is the only way in which we are able to measure movement across the line of sight; and even when we know the angular distance traversed by the star we can obtain no idea of the real distance which it traverses unless we also know the distance of the star from us.

Examples of stars whose "proper motions" can be measured

Another difficulty arises from the proper motion of our own sun; for since we observe always from the standpoint of the solar system, whatever proper motion it may be subject to will appear, reversed, as a factor in the apparent motion of any star. The determination of the actual motions of the stars is therefore an exceedingly difficult and complex matter. It has to be extricated, if possible, from all these complicated details.

The angular proper motion, however, is the first thing to obtain, and this has been successfully measured in the case of a considerable number of stars. The star with the largest observed angular motion is known as "Barnard's Runaway Star", having been discovered by him in June 1916; it is a tenth magnitude star in the constellation Ophiuchus and has an annual proper motion of 10 3 seconds of arc. The actual distance signified by this depends, of course, on the star's distance from us; its parallax is approximately $0''.5$, whence we find that it moves across our line of sight at the rate of about 61 miles per second. Many other stars have been discovered which move at a swifter pace than this. Thus the star Groombridge 1830 has an annual proper motion of $7''$ and moves with a velocity of over 200 miles per second, and the brilliant star Arcturus travels 90 miles per second though its proper motion is only $2''.3$ per year. The swiftest of all on record is the very distant star R. Z. Cephei whose velocity is calculated by Shapley to be about 680 miles a second though its proper motion is barely one-fifth of a second. It will be at once seen, therefore, that angular proper motions are only relative; they are qualified and determined by our distance from the star. They represent the movements of the stars, as it were diagrammatically, and as seen projected upon the background of the sky. Much additional knowledge is required in most cases in order to give absolute meaning to the diagrams.

Are stars that seem to move fastest those nearest to us?

Keeping these limitations in mind, however, the consideration of the angular motions of those stars for which it has been ascertained is interesting, and opens up many speculative questions. It would be naturally expected that the observed large proper motions would belong almost invariably to the brightest stars, since these

may be taken as being, on the whole, nearest to us; and, of course, the nearer the star, the greater an equal real motion will appear. But this is by no means found to be the case. Of one hundred and two stars known to have a proper motion of as much as one second of arc in the year, or a greater proper motion than that, sixty-four are invisible without the use of the telescope; that is to say, they fail to reach the sixth magnitude. Yet these stars have the largest proper motions which have been discovered.

Position in space no criterion of the velocities of stars

The fact is a startling one. What does it imply? Are these faint stars really nearer to us than their feebleness would seem to suggest, or are their actual velocities extraordinarily enormous? In either case, under what law can we explain their movements? Is there some unknown force producing ever-increasing velocities in the stars as they recede further from us into space? Or is there, perhaps, an unrecognized special class of stars combining feeble luminosity with excessive swiftness?

Just as there is no uniformity in the real brilliancy of stars, so that a bright star of the first magnitude may be actually further away than a dull, tenth magnitude star, so there is no real uniformity in velocity; a sluggish movement does not necessarily imply greater distance, nor a rapid movement comparative nearness. In spite of this irregularity, however, it may be concluded that, *on the average*, swifter stars are nearer to the earth, and apparently stationary stars are enormously distant — just as, *on the average*, brilliant stars may be taken to be nearer to the earth than faint ones. It might therefore be justly expected that the apparent velocity of stars, taking whole classes together, would vary in regular ratio, according to magnitude. But so far this has not been found to be by any means the case.

The three stars with the largest angular motion are all telescopic objects — Barnard's star having the largest motion is of the tenth magnitude; the star C.Z. 5,243, which comes next with an annual proper motion of $8''.7$ is of the eighth magnitude; and the third, Groombridge 1830, with a motion of $7''$ annually, is below the sixth magnitude The only very swift stars of great brilliancy are Sirius, Alpha Centauri, Arcturus and Procyon, the swiftest of these being Alpha Centauri, which has a motion of over $3''\,5$ annually.

The star that appears to move the swiftest of all bright stars

This star is the nearest of all known to us, so that its distance has been measured, and its actual rate of progress ascertained. It moves at the rate of nearly $14\frac{1}{2}$ miles per second. The brilliant Centaur star is therefore by no means one of the really swiftest moving heavenly bodies, but its comparative proximity to us makes its movement appear great. Sirius also is comparatively near to us, and its actual motion has been reckoned at 10 miles per second. Procyon moves at the rate of nearly 12 miles per second The large observed annual motion is in all three cases chiefly due to proximity. Arcturus, on the other hand, is at a much greater distance, so that its real motion is very considerable

Not a single star of second magnitude is included in the list of the swiftest stars, and the average velocity of second magnitude stars is excessively low. This fact, and the great swiftness of many very faint stars, are two of the anomalies of star movements.

Another difficulty in measuring stellar velocity is that, in order to be visible in the telescope, the movement of a star must be at right angles to the line of vision. Radial motion or movement along the line of sight will not appear at all; and motions which are the resultant of a transverse movement, together with an approaching or receding movement, will be diminished to a degree proportionate to the amount which is thus rendered imperceptible.

The record of movement directly towards or from us by the spectroscope

Fortunately, the spectroscope is able to record these radial velocities towards or from us, by means of the displacement of the spectral lines; and by the application of photography these records have been

rendered so accurately decipherable that it has become possible to ascribe definite rates of movement along the line of sight to certain observed stars. For instance, it is known that among the bright stars Aldebaran is moving away from us at the rate of 34 miles per second, Capella at 19, Rigel at 14 and Betelgeux and Canopus at about 13 miles per second. Other bright stars are known to be approaching us at similar speeds — Altair at 20 miles per second, Alpha Centauri at 13 and Vega at 9. But among the fainter stars many move at much higher speeds, one of the swiftest being the star with the catalogue number A. G. Berlin 1366. This star has the extraordinary radial velocity of 300 miles per second.

Stars which clearly move in concert across the sky

"Common proper motion" is taken to be an indubitable sign that the stars which take part in it are united in a system of some kind. Common proper motion does not mean mutual revolution, although mutual revolution does very frequently connect individual members of a partial system. The relation of Venus and the earth is the relation of bodies sharing in a common proper motion within a partial system — in this case, the solar system. Several examples of a similar kind were referred to when we were considering multiple stars. A few others may be named here. Two small stars in the constellation Libra, both of the ninth magnitude, but at the wide distance apart of five minutes of arc, move swiftly across the sky in perfect concert, accomplishing an annual transit of nearly four seconds. Two others, separated by the even greater distance of twelve minutes of arc, move in a concerted progress of more than one second yearly. One of these is a fifth-magnitude star in Ophiuchus, the other a seventh-magnitude star in the Scorpion. It is probable that many other distant stars are actually connected with the known small systems, and pursue similar motions in far places of the heavens under the same influence, but about these we can so far only speculate.

The difficult problem of the movements of the whole solar system through space

The problem which most intimately concerns us is the proper motion of our own sun among the stars. It is an essential principle of the universe that the sun itself must submit to the harmony of its movement; there is no more reason to believe that the sun is stationary than there is to believe that the earth is stationary. But the determination of the motion of our solar system through space is an extremely difficult problem, owing to the fact that we are in every way involved in this movement, and, with us, all our observations of external affairs. It is easy to see that it affects the apparent motions of all the stars in proportion to their distance and position with regard to the path of our journey; and if all the stars were motionless it would be a simple matter to determine the rate and direction of the movement of the solar system. But we know that the stars are all in motion, in all directions, and at greatly varying speeds. It has been discovered, however, that, underlying the apparent confusion of their movements, certain prevailing tendencies can be found which may safely be held to indicate the direction of the sun's progress. Herschel, in 1805, taking into account the movements of only a few brilliant stars, and tracing backwards the huge circular line of motion deduced from the fragmentary arc of their known movements, found for them a meeting-place in the constellation Hercules, and suggested that this would prove to be the point toward which the solar movement is at present directed. Further study, based on a fuller consideration of stellar movements, tends to confirm this result, while correcting it and defining it more clearly. It is an intricate question of the greatest probabilities, and of reducing to a minimum the number of movements for which it is unable to account.

The problem is to find a point in the sky such that the progress of our sun toward it will in itself account for the greatest number of stellar movements. Attempts to fix this position correctly have been made by many astronomers since Herschel.

How far the sun's journey through space has been mapped

Perhaps the most elaborate and successful of these have been the labors of Struve, who fixed the path of the sun's progress as being at present directed towards a point in the constellation Hercules, in that part which forms the extended left arm of the hero. It is, however, almost certain that the sun's path is not a straight line, but an enormous curve, and that the same point will not always define the direction of his progress. But the curve is so immense, and the sun's movement so comparatively slow, that this direction may not change, to an extent capable of measurement by even the most accurate known methods, within a million years or longer.

One other consideration must be noted. It is possible that this computed motion of the sun is not ultimate, but that the sun, in common with other stars, has also a drift along some vaster course. In traveling in a direction towards Hercules, our sun may do so as a member of some partial system; and in that case the discovered path would be a relatively small one pursued within the common movement of this system through space.

Is the sun a comparatively slow or fast moving star?

Careful observations in minute detail of the stellar movements left unaffected by this known direction of the sun's journey may in time throw some light on this possibility.

Very intricate studies of the rate of the sun's progress have also been undertaken, but it is impossible to clear up this matter finally without reliable knowledge as to the real distances of the stars. Many of the earlier attempts resulted in widely varying estimates, from as little as 5 to as much as 150 miles per second. In this problem, however, as in others, the spectroscope is proving a powerful ally, especially since photography has been brought in to minimize the certain errors which would otherwise attend the calculation of exceedingly delicate measurements of spectral displacements. Everything depends on the correct measurement of extremely slight shiftings, so that a more direct and more permanent record is required than can be obtained by the eye and hand of even the most skilful observer.

The support given by the spectroscope to the slow movement of the sun

By applying spectroscopic tests with modern instruments, first to stars in that portion of the sky towards which the sun is moving, and then to those in the region from which it is receding, a computation may be made with strong probability that it will give something nearly approaching the actual rate of solar progress. When a sufficiently large number of stars in each direction has come under observation, the result will be open to very little doubt. The spectra of stars in front of us will show the influence of movements of approach, while those behind will show the influence of recessive motion. Half the mean difference between the two sets of results may be expected to give the rate of solar progress. The results obtained in this way by Campbell are based on the radial velocities of about 1200 stars and indicate that the solar system is moving, relatively to the stars as a whole, with a velocity of about 12 miles per second; and Strömberg's more recent determination, based on 1400 stars, indicates a velocity of 12½ miles per second.

The problem of determining our distance from the stars is almost as old as astronomical research itself. It is certainly one of the most elusive of all problems, and is one that very directly affects many others. Questions concerning the physical constitution and relations of the stars depend upon the determination of distances for their elucidation. Real physical qualities, such as actual light-power, actual size, density, and the like, would be ascertainable if we knew the real distances, and real motions could be deduced easily and with certainty from apparent movements.

Indeed, the determination of distance is the one factor chiefly necessary to convert the relative or subjective knowledge acquired by observation into the absolute terms of its meaning to the body itself.

The enormous difficulty of the problem of measuring stellar parallax

But the difficulties in the way of determining the distances of stars are enormous. There are no fixed points, no known landmarks, no criteria for comparison. The only possible means open to us is the measurement of stellar parallaxes. From the time of Copernicus, parallax has been the object of much careful investigation. Astronomers have spent an immense amount of time and labor in studying the apparent displacements of the stars due to the earth's orbital journey round the sun. This displacement is called the star's "parallax". Of course, this study of stellar parallax became the most absorbing of astronomical interests when the Copernican theory was first launched, and it began to be believed that the earth moved in an orbit. For if parallactic displacements could be observed in the stars, the proofs of that theory would be still more complete. If, on the contrary, none could be observed, the Copernican theory would involve a distance between us and even the nearest stars which was in those days utterly incredible.

In the end, both of these facts have been established. Stellar parallax, though always exceedingly small, has been observed and measured in numerous cases. On the other hand, large numbers of stars have been carefully and unremittingly observed without betraying any signs whatever of such displacements.

Parallax is an effect of perspective. For example, if a coin be held out at arm's length and one eye is closed, the coin will be seen projected upon, say, the window, in some position which can be definitely noted — for instance, at the meeting of two bars of the frame; if then the closed eye be opened and the other shut, the coin will be seen projected on a different part of the window. If, while the coin remains fixed, the point of vision be moved in the form of the earth's orbit, the coin will be seen to perform a parallactic orbit upon the window. If the coin be held nearer to the eye, the orbit which it thus traces will be larger.

The calculations that fix the distance of the nearest star

This demonstrates the basic principle of stellar parallax. The parallax of any star is the angle subtended, at the distance of the star, by the mean distance between the earth and the sun. In other words, it is half the angular distance between the two positions of the star as seen, for example, in January and July. This angle being known, we are able to estimate the distance of the star. For, the distance between earth and sun being 93 millions of miles, the actual distance at which this line of 93 millions of miles is subtended by the given angle is easily discovered. In the case of an angle of one second, the distance of the star will be 206,265 times 93,000,000 miles, or about 20,000,000,000,000 miles. This is often used as a unit of stellar distances and is called a "parsec"; it is equal to the distance traveled by light in 3.3 years. The nearest of all known stars, namely the multiple star Alpha Centauri, has a parallax of only three-quarters of a second, from which its distance is calculated to be about four and one-third light-years. The star with the second largest known parallax seems to be Barnard's Runaway Star already referred to, its parallax being a little over half a second.

No approximately known distances of some of the great stars

Thus the two nearest stars are found to present as great a contrast as possible, the first being one of the three supreme stars of the heavens, and the second an insignificant object which is not visible at all except with the assistance of a telescope. A large proper motion has proved, on the whole, a safer guide than brilliancy in indicating stars likely to show a measurable parallax. About one-half of the stars with sensible parallaxes are among the swiftest stars — that is to say, those with an angular motion of one second and upwards in a year. Among first-magnitude stars, parallaxes have been obtained for the following: Sirius, which is at a distance which light would travel in nine years; Procyon, at a distance of thirteen light-years; Altair, at

fifteen light-years; Aldebaran, at fifty-eight light-years; Capella, Pollux and Vega, at distances of forty-four, fifty-one and thirty-six light-years respectively. Several of the first magnitude stars are so far away as to have no sensible parallax; such is the case with Canopus, the second brightest star in the heavens.

The use of photography in showing the motion of the stars

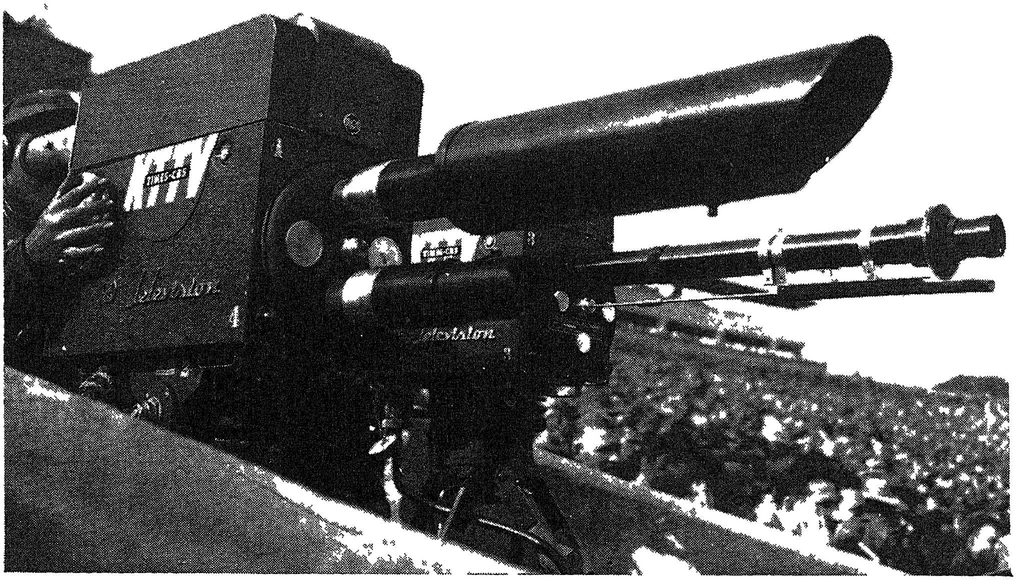
Some of the figures just given are subject to a rather wide range of uncertainty because accurate measurements of parallaxes are extraordinarily difficult to obtain. The whole amount, except in the nearest stars, is so minute that it is impossible to secure any very reliable results from comparisons of periodical positions of the star according to its absolute position in the sky — as measured, so to speak, by its latitude and longitude in the hollow sphere of the heavens. This absolute method of measuring parallaxes has been applied successfully to a few stars, notably, Alpha Centauri and 61 Cygni, but the method adopted by most modern parallax-searchers is a differential one, based on the use of comparison stars. The angle between the star under observation and some other star presumed to be considerably more distant is measured at regular intervals, and the results are compared. Periodic variations may safely be put down to parallax, especially if, as is now always done, several comparison stars are chosen, and the parallax is arrived at by combining the results. Photography has made this method easier, more certain, and applicable on a wider scale. The position of the star can be tested in relation to a large number of stars — as many, indeed, as are found on the plate in a suitable position; for only those stars are suitable which lie more or less in the directions towards which the major axis of the parallactic orbit points.

Of course, there is always the chance of error arising from parallactic displacements in the star which has been chosen for comparison, especially if this star be nearer to the earth than was imagined. Hence the great value of a permanent record providing many comparison stars and thus minimizing the likelihood of error.

The diameters of stars computed from their parallaxes

It is clear, however, that the results of this method can never be more than relative; and on this account they may make out the parallax to be too small and hence the star's distance to be greater than it actually is, though the real distance of the star cannot be greater than its calculated distance, provided the measurements are made accurately. Thus, parallaxes carefully measured by means of comparison stars serve to fix definitely an upward limit to distance; and as the measurements are extended on a wider and wider scale they may eventually be relied upon to give very nearly accurate real results.

The diameters of seven bright stars were recomputed in 1940 by G. H. Herbig, using new values of their parallaxes. Their angular diameters had been measured years ago by F. G. Pease by means of an interferometer. While the diameters of Aldebaran (31,000,000 miles) and Arcturus (20,000,000 miles) changed little, the star Alpha Herculis, or Ras Algethi, (690,000,000 miles in diameter) advanced from second to first place, displacing Antares (245,000,000 miles in diameter). Antares is also exceeded by two variables, Betelgeuse and Mira, whose diameters at maximum are 360,000,000 and 395,000,000 miles respectively. All these stars are of the red type and extremely tenuous.



CBS

Televising a football game. The left-hand camera has a 24-inch lens for close-ups and a 17-inch lens for medium shots. By a lens adjustment the other camera can switch from long shots to close-ups.

Jack Partington, Jr., Roxy Theater, N. Y.

In a television studio: preparing for the televising of a play. A number of intricate problems involving lighting and the position of the actors must be solved before the cameramen swing into action.

PRACTICAL TELEVISION

Electrical Transmission and Reception of Moving Images

(Photographs by Haussler, courtesy of National Broadcasting Co unless otherwise indicated)

TELEVISION means "seeing at a distance." Telescopes and opera glasses help us to see distant objects, but television cannot be compared to devices like these. For one thing, those watching a typical television program not only "see at a distance" but also "hear at a distance." They are *seeing* a reproduction of the scenes recorded by the television camera at the same time that they are *hearing* a reproduction of the sounds that accompanied the visual part of the program. The light-waves and sound-waves originating in the studio have their patterns impressed upon electromagnetic waves,which are sent out through space. These waves are picked up by the television set. Inside the set they are changed into the swiftly changing patterns of light that give the television picture and into a pattern of sound-waves corresponding to the one that struck the eardrums of the studio audience an instant before.

In the twenties of the present century television was a laboratory curiosity. The public at large heard from time to time that scenes recorded by cameras were shown almost simultaneously through the medium of the same electromagnetic waves that had made radio possible. The exciting possibilities of this new invention were evident enough, but the general feeling was that many years would elapse before its promise would be fulfilled.

Today television has passed beyond the laboratory stage; the television industry is growing by leaps and bounds and already ranks among the leading electronic industries. Millions of sets are in the hands of the public, and television viewing has brought about radical changes in the habits and customs of large sections of the population. Already a vast variety of programs has been telecast, appealing to all.

There have been dramatic performances —serious plays, comedies, farces, murder mystery plays—with outstanding stars of the stage, the movies and radio. There have been hour-long reviews replete with vaudeville acts of every description. Masters of ceremonies have interviewed celebrities and near-celebrities; commentators have analyzed the daily grist of news. There have been special telecasts for children: puppet shows, Western movies and playlets presenting famous historical or fictional characters. Many telecasts have not originated in studios but have constituted on-the-spot reporting of historical happenings and sports events of many kinds. Some of these telecasts have made history.

Mechanical television systems

All television is based on the photoelectric cell which produces an electric current in proportion to the amount of light that shines upon it. Now the things we see—or want to see by television—may consist of many different degrees of light and shade. How can we send these out all at the same time?

Before we attempt to answer this question, let us ask it in another way. How can we mail to a friend a jigsaw puzzle far too large to fit into an envelope? A practical method immediately suggests itself. We can take the puzzle apart and send it bit by bit, in several envelopes, until our friend has received all the pieces. When he puts them together again he will have the original picture. Now let us return to our first question which asked how we sent all the degrees of light and shade in a picture at the same time.

The answer is, we do not. In our present system, we break down the picture into thousands of tiny dots of different bright-

THE SAME SUBJECT SEEN ON A PHOTOGRAPH (AT LEFT) AND ON A TELEVISION SCREEN

ness which act upon a photoelectric cell in turn. At the receiving end all these dots are put together again, and this is done so quickly that the eye sees an unbroken picture.

An early form of television transmission, invented by the German Paul von Nipkow, employed a little spinning wheel, which was known as a "scanning" disc. To "scan" means to look at something point by point, and this was just what the scanning disc did. It had a number of holes arranged in the form of a spiral around the rim. The disc was so designed that when it spun a beam of light passing through the holes was guided like a thin pencil over the picture, person or scene that was to be scanned. Each time that the disc turned, every point of the picture was covered, one after the other, in far less time than it takes to tell. Remember that the whole scene was not illuminated at once; the light fell on only one dot at a time; but this dot of light, quick as a flash, skipped over every part of the picture many times each second.

Every picture reflects light thrown upon it—that, indeed, is how we see things, for the reflected light enters our eyes. Different parts of a picture reflect more or less light—that is how we distinguish between light and dark. In the mechanical television system that we are describing, the beam of light passing through the scanning disc was reflected from the picture, not directly to the eye of the distant observer, but to a photoelectric cell, which, as you may know, is often called an "electric eye."

If you have read carefully up to this point, you will understand that the photoelectric cell received in quick succession light impressions from every single point of the picture that was to be televised. The light impulses in question were stronger or weaker as the point of the picture from which they came was lighter or darker. Since the photoelectric cell turns light into electric current, the cell used in televising produced a current that varied as the light shining on the cell was stronger or weaker. This current was sent to distant places along special cables or by means of radio waves.

At the receiving end the current was picked up in the usual way, and it was made stronger or, in more technical language, "amplified." It was then fed into a certain kind of electric lamp that glowed more or less brightly as the current varied. The lamp shone on a small screen at which the observer looked through another scanning disc, timed to run at exactly the same speed as the one on the sending side. (This was called "synchronization," from two Greek words meaning "together" and "time.") It could and had to be done so accurately that the holes in the two discs scanned corresponding points at the same time. The scanning disc provided what seemed a continuous picture.

The result of all this was that the observer at each instant saw a tiny part of the screen illuminated just as brightly as

was the corresponding part of the original picture. As the scanning took place so very quickly, the eye saw the entire scene illuminated and a moving image of the original scene appeared.

In some variations of this system the scanning disc was replaced by revolving mirrors which served the same purpose. All these methods were called mechanical because they required the *movement* of parts like discs and mirrors.

Electronic television

Mechanical television systems like these are now a thing of the past; modern television is based on an electronic system. As the name suggests, electronic television employs electrons, those tiny bits of negative electricity. Electronic methods have proved to have many advantages over mechanical ones because electrons can be moved practically instantaneously and without noise.

Before we examine the two outstanding systems of electronic television that have been devised—those of Philo Taylor Farnsworth and Dr. Vladimir Kosma Zworykin—it would be well to make a rapid review of the striking phenomena that make such advances possible.

How electrons are produced

Those small particles of negative electricity called electrons may be produced in several ways, though we need consider only three. The photoelectric cell provides one such way. We have mentioned that the photoelectric cell produces an electric current in proportion to the amount of light that falls upon it. Let us now be more exact in our statement: when light falls upon certain photoelectric materials such as cesium or potassium, electrons are thrown out; the number of these electrons coming from any spot depends upon the amount of light falling upon that spot; a moving stream of these electrons constitutes an electric current.

Under the proper conditions, if instead of light we use electrons to bombard our cesium, several times as many so-called secondary electrons will be thrown out. These secondary electrons differ in no material respect from the electrons that caused them to be ejected from the cesium's surface. This provides us with our second method for the production of electrons.

A third fertile source of electrons is a heated filament such as we see glowing in our radio tubes.

Applying forces to electrons

An electron can be made to "behave" as we wish if we apply to it certain forces of an electric or magnetic nature. We can change the direction and speed of an electron's movements with the proper arrangement and combination of these electric and magnetic fields. Just as a tennis ball can be deflected by a wind, so can an electron be swerved in its path by the proper electric and magnetic influences to which it responds. Thus we can think of setting up electric and magnetic "winds" that will "blow" the electron along chosen paths.

The Farnsworth system

The system of telecasting devised by Farnsworth, consisted of two essential parts: an image dissector and a multiplier. Unlike the mechanical system we have already considered in which light from successive points was brought bit by bit to the photoelectric cell, in Farnsworth's system the light from the entire scene was focused on a cesium-coated plate in the dissector.

From each spot of the cesium's surface on which light falls, a stream of electrons was ejected. The number of electrons issuing from any spot was proportional to the amount of light falling on that spot. A dark point on the original picture was represented by relatively few electrons, while a light point gave rise to relatively many. Thus the image originally composed of light was translated into a new image composed of electrons.

Since a moving stream of electrons is like an electric current, the inventor could have introduced into the dissector a tiny conductor of electricity. As he moved this conductor point by point over the electron image, there would flow into

it an electric current that would be stronger or weaker according to whether the electrons at that point were, respectively, many or few.

However, it would have been inconvenient to use such a tiny conductor in this manner. Instead, by means of the magnetic and electric forces that can influence electrons and which we have already described, all the points of the electron image were made to pass in very quick succession over a small hole leading into the multiplier.

How the multiplier worked

The name multiplier describes exactly the instrument to which it was applied. The multiplier multiplied the number of electrons entering into it. We are already prepared for the method used. The entering electrons were hurled against a cesium-coated plate. This gave rise to many more electrons. These electrons were in turn thrown against cesium, again giving rise to increased numbers of electrons. The procedure was carried on several times, and the multiplication of electrons proceeded rapidly.

It must be recalled that the electrons entered the multiplier in groups. Each group represented the particular part of the picture which gave rise to it. When each of these groups had been multiplied a given number of times, a wire withdrew the current that these electrons represented. After further steps, this current from the multiplier was sent out through space or over coaxial cables.

It has taken us several minutes to read about the action of the dissector and the multiplier. In actual practice the entire electron image was dissected, multiplied and telecasted many, many times in one second.

Dr. Zworykin's iconoscope

Telecasting systems today employ some form of the tube that was called by its inventor, Dr. Zworykin, the iconoscope (from the Greek words *icon,* meaning "image," and *scope,* signifying "view"). The iconoscope is a tube used to change an entire optical image into electrical energy. We may think of this tube as consisting of two principal units.

The first unit consists of a thin sheet of some non-conductor of electricity, such as mica, which has on one side many thousands of tiny, separated cesium droplets, and on the other side a metal plate. The cesium-spotted side is called the mosaic and the opposite side is called the signal plate.

When no light shines upon it, the mosaic may be considered to be in a state of equilibrium with amounts of positive and negative electricity that balance each other. This neutral condition changes very quickly when light is focused on the cesium droplets. Every droplet will then have falling upon it light from some particular part of the entire picture. Though exceedingly small, each droplet will act like a miniature photoelectric cell and will discharge electrons in proportion to the amount of light that strikes it.

The positive charge on the mosaic

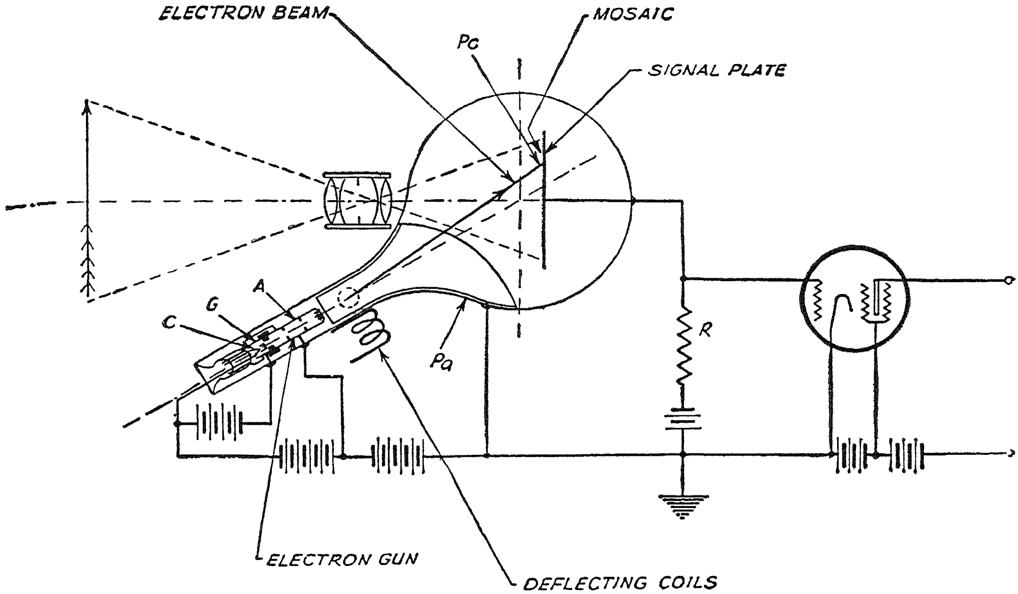
The expulsion of these electrons, or negative electricity, will destroy the state of balance that existed in the cesium before its exposure to light. The positive electricity in the cesium will thus be greater in its effect than the negative electricity which remains behind. Hence we say that the mosaic has become positively charged. This positive charge on the droplet will exert a force on the signal plate through the separating layer of mica. The plate will become negatively charged in proportion to the positive charge on the mosaic. In the language of the physicist we would describe this effect by saying that the charge on the mosaic had induced an opposite charge on the signal plate.

If we now returned to the mosaic the negative electricity which it had lost because of its reaction to light, we would again affect the signal plate. To restore this negative electricity to the cesium on the mosaic would render the negative charge on the signal plate superfluous. This will result in a current impulse in the signal lead that connects the signal plate to the amplifier.

The second unit within the iconoscope contains a filament which when heated gives off electrons. The proper electric and magnetic forces then concentrate these electrons into a thin beam which is directed against the mosaic. In much the same manner that this writer directs his pencil across the page, and having come to the right-hand margin drops to the line below to begin writing again at the left margin, so does this "pencil" of electrons from the filament sweep

We are now ready to study the iconoscope as a whole. The object to be telecasted has its image focussed on the mosaic. Instantly each cesium droplet begins to give off electrons in proportion to the amount of light falling on it. The droplet thus acquires a positive charge. On the signal plate behind each droplet there accumulates a proportional negative charge.

Now the beam of electrons from the filament comes into play. It sweeps



HOW THE ICONOSCOPE CONVERTS A LIGHT IMAGE INTO ELECTRICAL SIGNALS

The Iconoscope is a highly evacuated glass vessel. The scene, represented by the long arrow on the left, is focussed on the mosaic through the transparent wall of the Iconoscope by means of the lenses. The electrical charges which result from the mosaic's reaction to the light cast upon it are released by the electrons sent against the mosaic by the electron gun. Discharging the mosaic induces current impulses in the signal plate which are withdrawn as representative of the original optical image. The deflecting coils control the movement of the electron beam over the mosaic.

across the mosaic, line by line. But here the resemblance stops, because while the writer has left marks on the page as his pencil moved, the beam of electrons has "erased" in quick succession the positive charges of electricity which were the marks left upon the cesium droplets exposed to the light. In actual practice it is usual for the electron beam to scan alternate lines on the mosaic, and having come to the bottom, the beam returns and scans the omitted lines. This practice, called interlaced scanning, results in a final image with less flicker.

across the mosaic, doing the odd-numbered lines first and then returning to do the even-numbered lines, until 525 such lines have been traced, and this scanning process is completed thirty times in one second! Each positively charged droplet is driven to equilibrium by the electron beam. The process in which the positively charged droplet is discharged results in a current impulse which is sent to the amplifiers.

As the electron beam comes to the end of each line, a synchronizing signal is added to the train of electrical impulses which represent the picture. Then, as

While a scene is being played in the studio, a director watches it in the control room on the television screen panels in front of him and telephones instructions to the Iconoscope cameramen who wear headphones

the electron beam completes its last line at the bottom of the picture on the mosaic and is ready to swing back and up to begin again its course of scanning, another synchronizing signal is added. These synchronizing signals are needed to keep the receiving apparatus running in exact accordance with the transmitter.

What is represented by the impulse of electricity withdrawn from the signal plate in the iconoscope and sent to the amplifier? Let us recall that this impulse was proportional to the positive charge on the cesium droplet in front of it; that the cesium particle's positive charge was proportional to the number of electrons which had been expelled; and that the expelled electrons, in their turn, were proportional to the amount of light which fell on the droplet. Hence, we see that this final small current of electricity represents one tiny part of the picture to be telecasted.

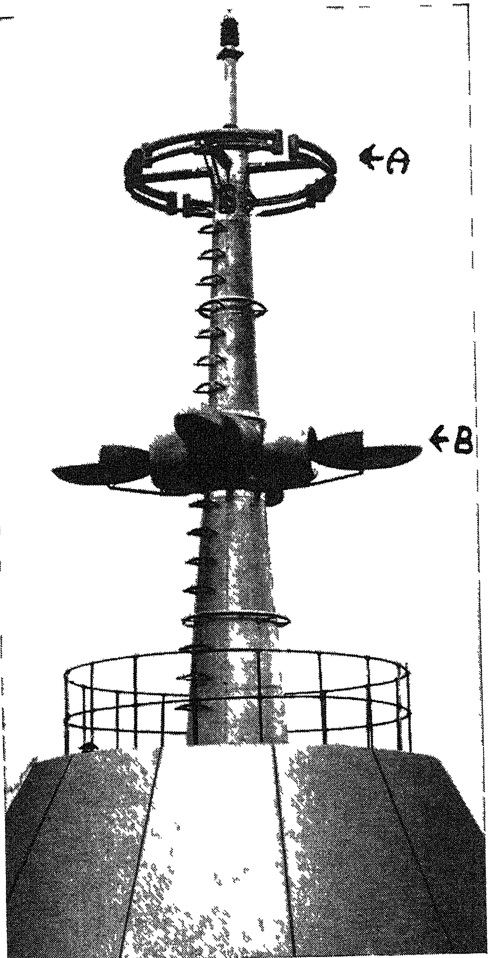
If we can now receive these impulses in the same order and as speedily as they were given off, we shall be able to change them into an optical image which will be a representation of the original picture.

Transmitting the picture

The British Broadcasting Corporation, in a booklet describing its London television station, gives the following interesting description:

"The radio transmitter used for television has much in common with transmitters used for sound broadcasting, in that the signals are sent out superimposed on a carrier-wave. The carrier-wave may aptly be likened to an endless belt conveyor as installed in some warehouses. The conveyor rolls along silently by itself, conveying nothing, until an assistant at one end of the counter wraps up a parcel of goods and throws it on to the belt. The parcels are carried down to the other end and deposited in a receptacle where the customer waits.

"In sound broadcasting the parcels are speech or music, the assistant is the artist in the studio, the carrier-wave of the radio transmitter is the conveyor and the customer is the listener. Similarly, in television, the parcels are elements of picture to be conveyed to the viewer by the carrier-wave which forms the conveying link through the ether.



NBC'S TELEVISION TRANSMITTING ANTENNA ATOP THE EMPIRE STATE BUILDING

To send television signals consistently beyond the horizon is one of television's most difficult engineering problems Since the distance of the horizon increases with height, television transmitting antennas are located as high as possible With an antenna as high as this one, more than 1250 feet tests show that satisfactory reception can in general, be had to distances somewhere between twenty five and fifty miles Antenna *A* radiates the sound component, *B*, "the video", or picture, component

"In view of the great number of picture elements which have to be transmitted each second, a large band of frequencies is required Present standards require approximately 4 5 million cycles per second. Consequently, the conveyor belt must be sufficiently wide so that the picture elements which are laid side by side across it, won't fall off the edge. The band of picture elements, or frequencies, must therefore be less than the carrier frequency. In actual practice, it is about one-tenth of the carrier frequency."

The television receiver

The television signals transmitted through space are picked up by the receiving aerial and passed to the receiver. This receiver functions quite like the sound receivers with which we are familiar, except that the output is not passed to a loud-speaker, but to a reproducing tube.

The reproducing tube is, in general, a cathode-ray tube, though it is called the "Kinescope" by one manufacturer and the "Oscillight" by another. We shall adopt the engineers' shorthand and call it a CR tube As shown on page 4080, the CR tube looks like a top with a long, broad peg.

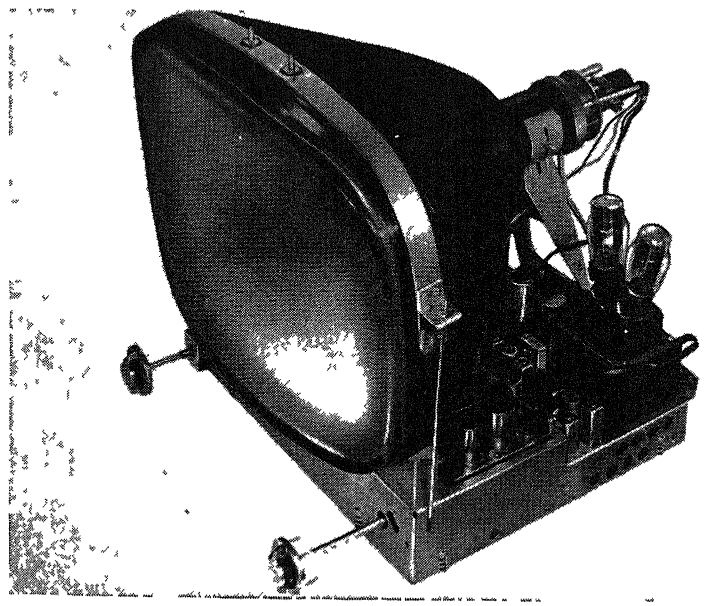
The tube is a highly evacuated glass vessel and we may, for convenience sake, consider it to be made up of two units The first unit is an electron gun located in the thin neck of the tube. This gun manufactures electron bullets from a heated filament These electron bullets are aimed by means of electric and magnetic forces such as we have already discussed. Furthermore, the number of electron bullets shot will depend on the strength of the signal impulse received from the sending station. A strong impulse will result in many electrons being shot out, while a weak impulse will result in fewer bullets to be fired at the target.

The second unit is the target. It is a thin, practically transparent layer of fluorescent material deposited on the inside of the transparent glass at the bulbous end of the CR tube. This chemical coating will glow with a visible light for a short time when bombarded with electrons. The amount of glow will depend upon the number of electrons which strike the screen, and this light will be visible through the glass. The more electrons that strike, the stronger will be the light coming from the screen We are now ready to watch the CR tube at work.

The electron gun's heated filament gives off electrons. By means of our electric or magnetic forces, these electrons are concentrated into a narrow intense

beam which sweeps across the screen, line by line. Wherever the beam strikes the screen, our chemical coating will glow. Since the number of electrons in the beam is constantly changing with the strength of the signal coming from the sending station, spots on the screen will glow more or less brightly.

The electron beam in the CR tube is very accurately co-ordinated with the sending apparatus by means of the synchronizing signals sent out by the transmitting station. As a given spot on our original picture is being translated from light to electricity, our electron gun in the CR tube is being aimed at a similar spot on the reproducing screen. When all these spots have been filled in on the fluorescent screen, they will resemble the original picture in their relative positions and intensities. The electron beam moves so quickly over the screen (tracing as it does 525 lines thirty times each second!) that the observer's eye sees a complete picture instead of the thousands of chemical spots, each glowing with different degrees of brightness.



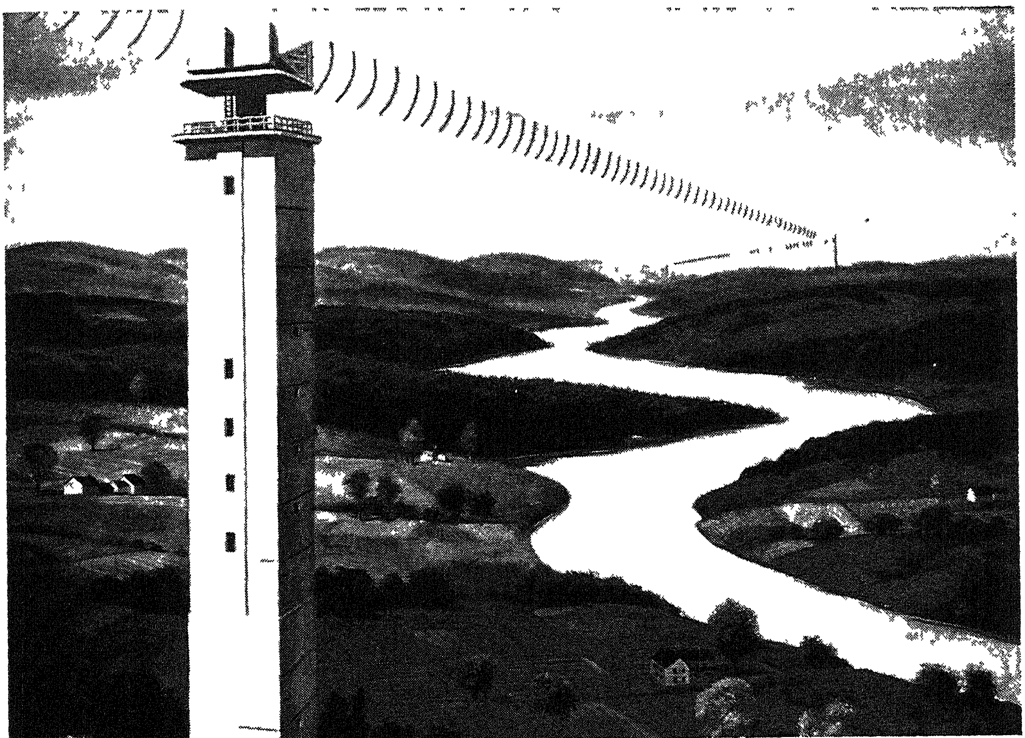
Chassis of a modern 30-tube television set. It combines power and precision for outstanding reception even in so-called "fringe areas."
Sylvania

Physical conditions impose restrictions on the size of the image that may be viewed directly on the glass face of the CR tube. The early images were quite small, one enterprising manufacturer even featuring a picture about the size of a postcard. Today much larger tubes are used; the 21-inch tube is becoming increasingly popular. The rectangular-shaped tube has passed the experimental stage and is now manufactured in quantity. It makes it possible to utilize more screen area in the production of the picture. To overcome the difficulties of enlarging the cathode-ray tube in order to get larger images on the screen, television engineers have developed projection tubes with brilliant images that can be enlarged considerably, particularly for theater use. Voltages ranging up to a hundred thousand have been employed on theater projection tubes to obtain the brilliant images required for television reception in theaters.

The frequencies required for television purposes present peculiar limitations and difficulties. In 1937 Arthur Van Dyck wrote in Television, Vol. II (RCA Institute Technical Press, New York):

"The unusually high frequencies give rise to new problems in the really wireless part of the system, that is the medium between the transmitting and receiving stations. Everyone is familiar with

existing conditions in sound broadcasting and knows that the quality of the service received depends upon the power of the transmitter, the distance between transmitter and receiver and the degree of static or other interference present in the receiving neighborhood. With the higher frequencies used for television, the same factors are present, but in different ways and degrees. The television frequencies are frequencies, behaving more like light, act somewhat as does a powerful searchlight. They do not follow the earth's curvature very well, or go behind a mountain, or through a building. Therefore, they are more limited by obstacles of the earth's surface, and . . . the transmission will be more effective, the higher the antennas are located . . . Similarly, better reception is had by locating the receiving antenna as



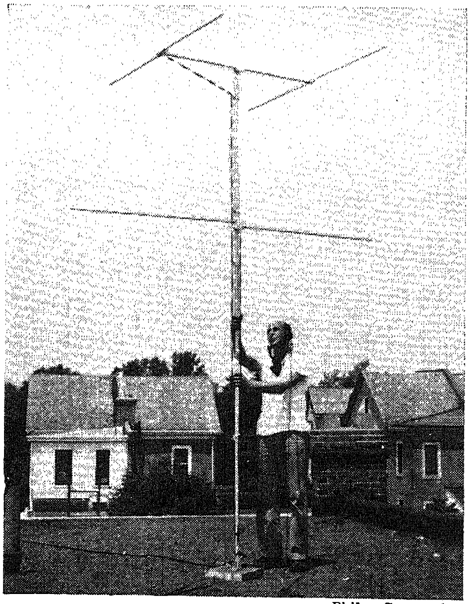
American Telephone and Telegraph Company

Effective transmission of television signals is limited by the horizon and the strength of the signals. To provide television across America a new skyway of radio-relay towers has been erected. Each giant tower receives the signals from the one preceding it and passes them on to the next tower.

so high that the waves approach in behavior that of light waves. It will be remembered . . . that there is no difference in character between light waves, heat waves, ultraviolet rays, X rays, radio waves, except that of frequency. All are disturbances in space of the same character and differ only in frequency. We are accustomed to ordinary radio waves going around the curvature of the earth, over and behind mountains, and through buildings . . . but radio waves at television high as possible, and when television does come to the home, it will be advantageous in most cases to put an antenna on the roof, rather than a wire on the base board in the living room."

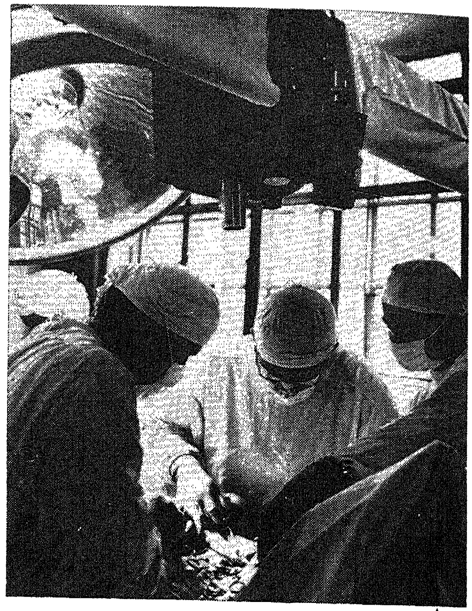
Van Dyck wrote the foregoing lines when television was still in the experimental stage. With the solving of many baffling problems, television engineers have built television into a thriving enterprise. Millions of listeners — and onlookers — follow television programs originating in a num-

TELEVISION SERVES IN MANY WAYS



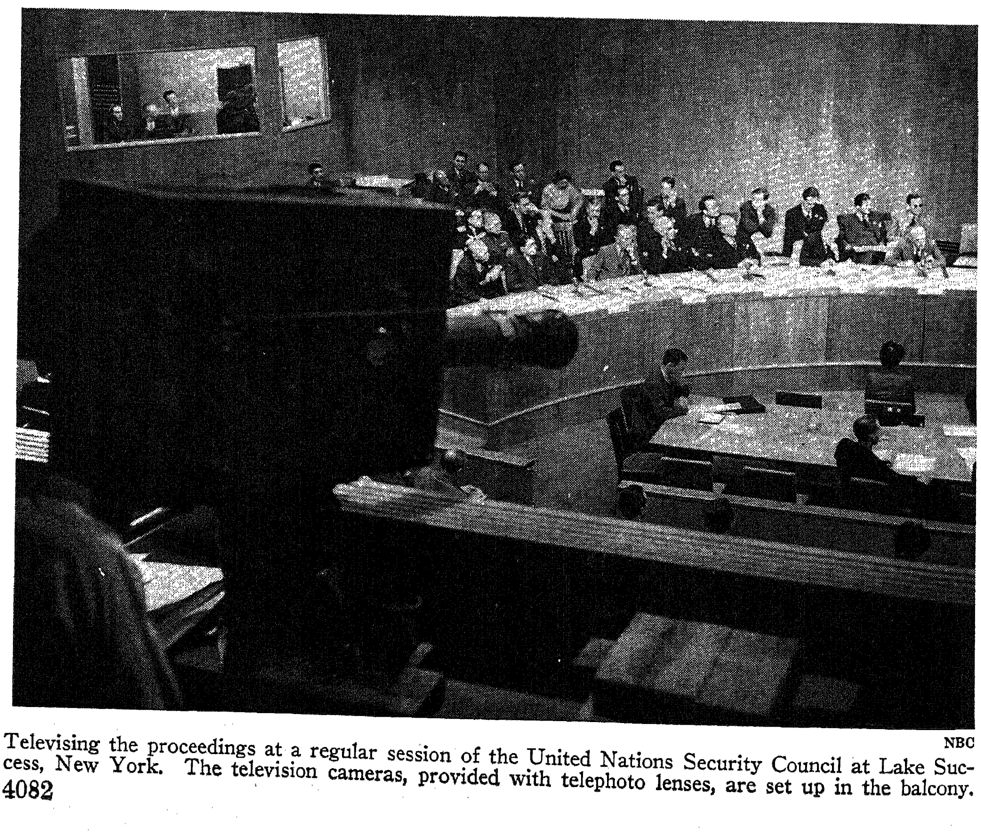
Philco Corporation

Serviceman setting up a television antenna for a private home. The lower antenna receives lower band signals; the upper one, high-band signals.



Acme

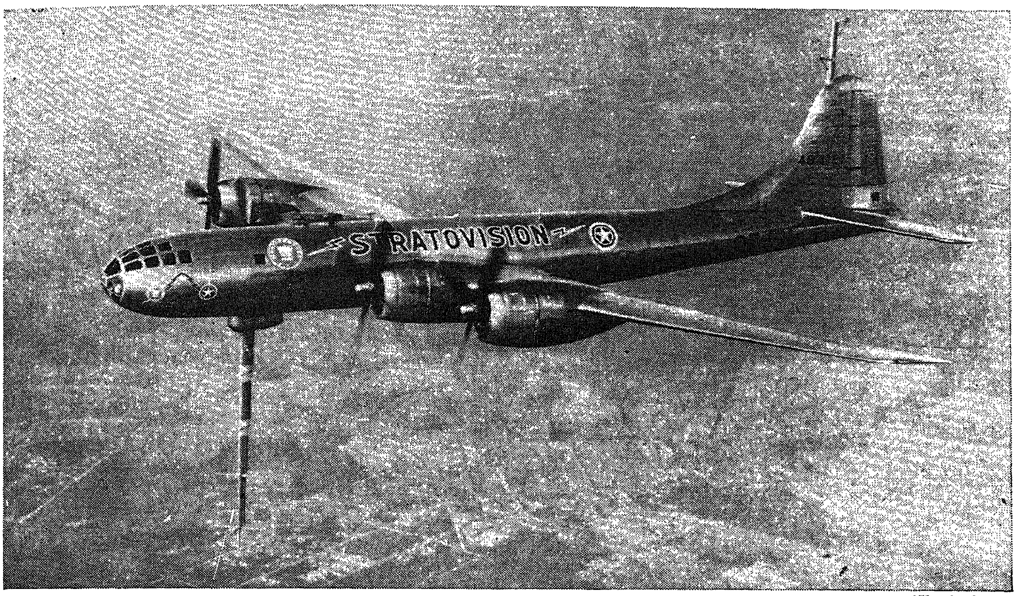
An operation in a New York hospital for the removal of a thyroid gland is televised for the benefit of 300 surgeons in a hotel two miles away.



NBC

Televising the proceedings at a regular session of the United Nations Security Council at Lake Success, New York. The television cameras, provided with telephoto lenses, are set up in the balcony.

SPREADING CULTURE FAR AND WIDE

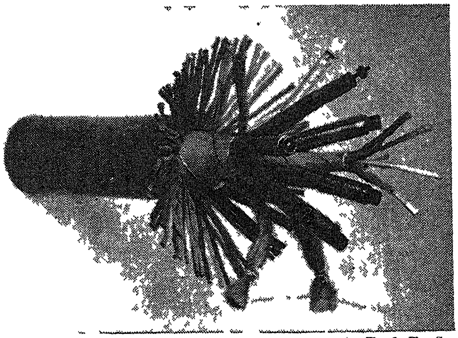


Westinghouse

A flying television station. This B-29, flying at 25,000 feet in the vicinity of Pittsburgh, rebroadcasts telecasts picked up from east coast television networks. Programs are picked up on the antenna projecting above the tail and rebroadcast from the mast-like antenna suspended from the nose.

CBS

Televising a concert given by the Philadelphia Symphony Orchestra, under the direction of Eugene Ormandy. Television makes it possible to see as well as to hear outstanding virtuosos and orchestras.



A T & T Co.

A view of one section of the coaxial cable used to carry long-distance network television programs between Washington and New York Coaxial cables are employed to transmit telegraph and telephone signals as well as television signals.

ber of telecasting stations. Already television is a rival of radio and, to a lesser extent, of moving pictures.

It is true that the radio waves used in television have a range that is limited practically to the distance of the horizon from the height at which the transmitting antenna is placed, or to a comparatively short distance beyond this horizon. But programs can now be effectively relayed from one telecasting station to another, so that a puppet show originating in Chicago can be shown simultaneously in Chicago and New York and with perfect clarity of sound and image in both places. Such programs are generally relayed nowadays by the coaxial cable — a special kind of cable that can carry high-frequency signals with very little loss.

Several other methods have been employed to relay television programs. Telecast signals have been sent over a microwave radio relay system. (Microwaves are high-frequency radio waves.) In this system giant metal lenses shape and aim the waves like a searchlight; corresponding metal lenses pick up and funnel the waves into a repeater for amplification and retransmission. Boosting stations are placed on hilltops at regular intervals along the way, and in this way the microwaves are relayed. Airborne television transmitters have also been employed; planes flying at great heights have served as relay stations. It is claimed that a succession of such planes stationed at appropriate intervals would make coast-to-coast telecasts possible at comparatively low cost. Neither the microwave radio relay system nor airborne transmission have proved as effective in relaying television programs over great distances as the coaxial cable.

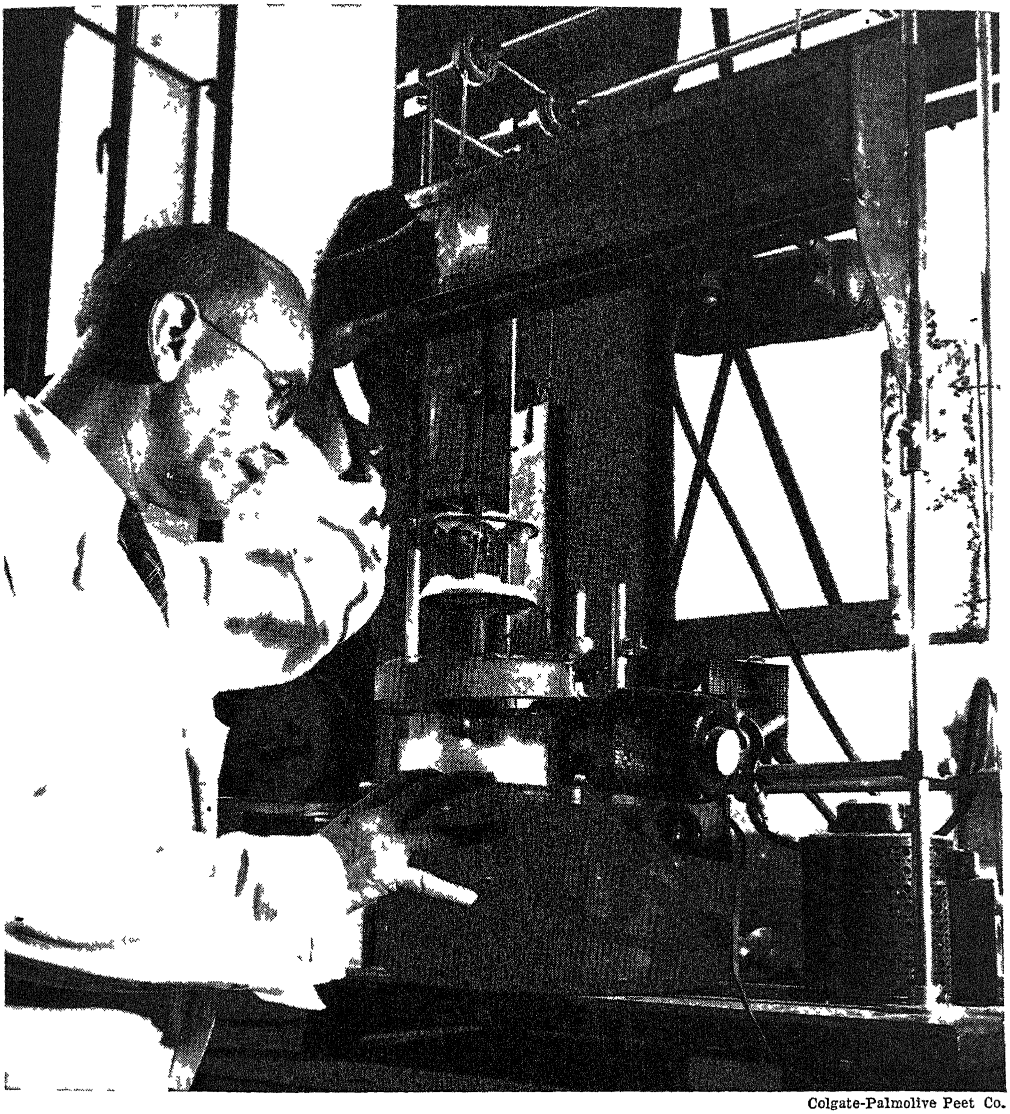
The use of outdoor or built-in antennas to bring in telecasts

Outdoor antennas are still used widely to bring in telecasts to private homes. A great deal of progress has been made with built-in atennas, however; in a number of areas where the television signals are particularly strong, no outside antenna of any kind is now required.

There seems to be no doubt that the television of the future will make great use of color. Several systems of full-color television are now available, although they are not yet in commercial use. In the color system developed by CBS (the Columbia Broadcasting System), a wheel with red, green and blue sections rotates behind the lens of the camera It filters the light emanating from the subject so that the colors are transmitted in succession. In the receiver, the picture tube forms the usual images in black and white. However, a second color wheel, which is synchronized with the one in the telecasting stations, changes the images back to their original colors. The wheel really causes a succession of images of different colors to be seen, but these appear to be a single color to the eye of the viewer.

The electronic system of full-color television

In the electronic system, favored by RCA (the Radio Corporation of America), red, green and blue light emanating from the subject is directed into separate lenses by special mirrors. Scanning tubes — one for each lens — convert the lens images into broadcast signals; the tubes send their signals in rotation. In the receiver the signals are transmitted to red, green and blue picture tubes. Mirrors then reflect the three images on to a single viewing plane; as a result the television screen shows a single full-color picture.



Colgate-Palmolive Peet Co.

A test to predict the effect of soaps and detergents in dishwashing. Detergents are made of chemicals that cause lowered surface tension and cohesion in the water used for cleansing. As a consequence the cleansing solution can more effectively penetrate the material that is to be cleaned.

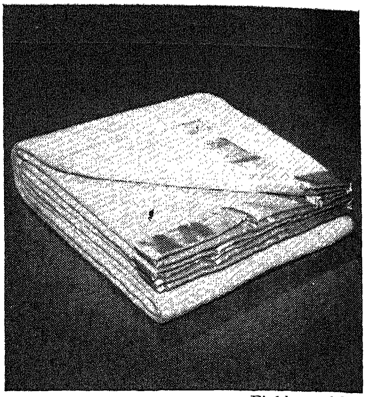
RECENT SCIENCE HIGHLIGHTS

Science is constantly pushing forward its frontiers in different directions. It lightens the task of the housewife with new cleansing agents; it makes railroad transportation safer and speedier; it provides short cuts in the training of airmen; it speeds up photographic processes; it introduces a bewildering variety of new fabrics; it creates new and vastly more accurate timepieces; it renders the tools of war more efficient.

On this page and the ones that follow we give you some idea of the progress that has been made in these directions.

Union Carbide and Carbon Corp.

A recent addition to textile fibers is Dynel. It is made from vinyl chloride-acrylonitrile resin. Above, the resin is extruded to form a tow. This is cut to staple lengths and then crimped. Finally, the crimped staple is sent on to the spinner, where it is twisted and drawn into yarn.

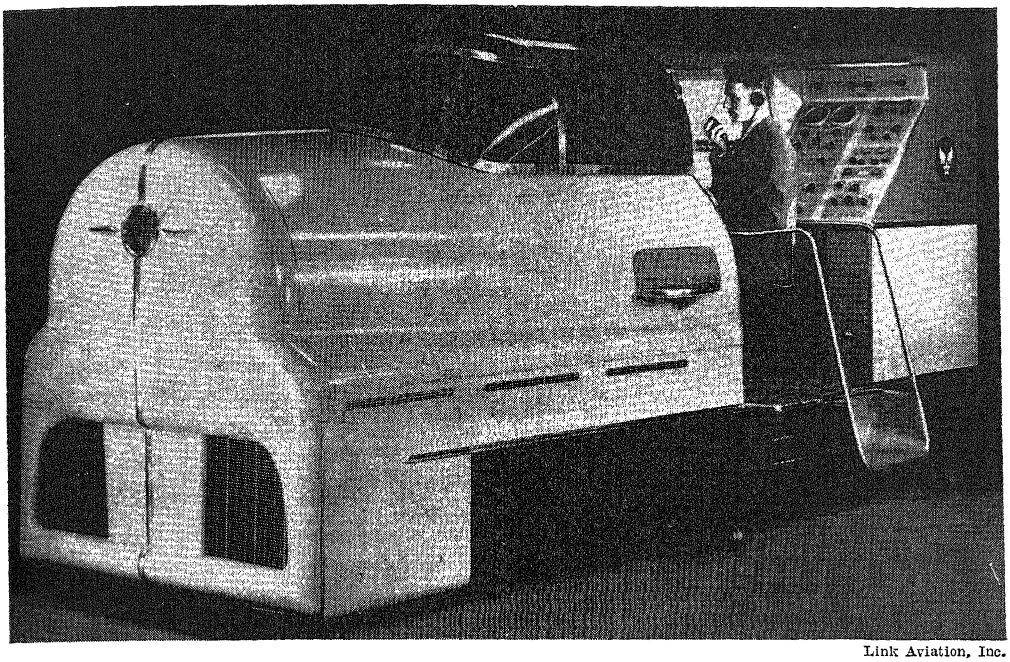


Fieldcrest Mills

This blanket, made of Dynel fiber, is warm, fluffy and resilient, and launders very easily. Dynel has a high degree of resistance to a great variety of inorganic acids and industrial chemicals; it is fire-resistant; it is immune to insect or fungus attacks. It is widely used for wearing apparel, such as sweaters, half hose, work clothing, suitings, sportswear and knitted jerseys, and for home furnishings, such as blankets, draperies, shower curtains, upholstery and rugs.

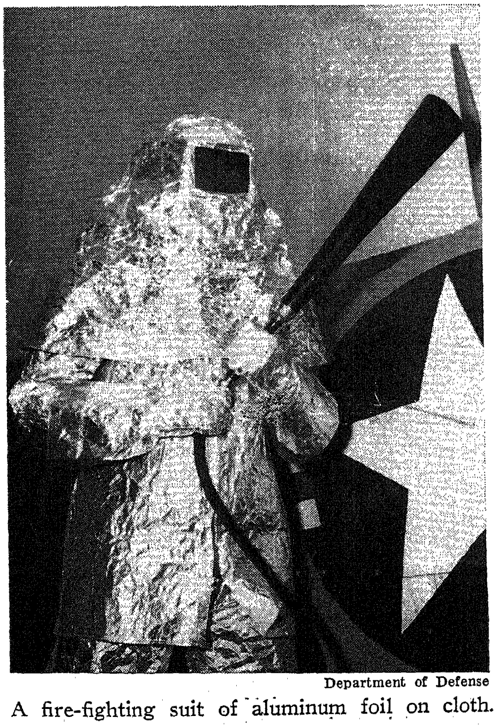
General Electric

A gas turbine-electric locomotive. The turbine generates the electricity that runs the big motors.



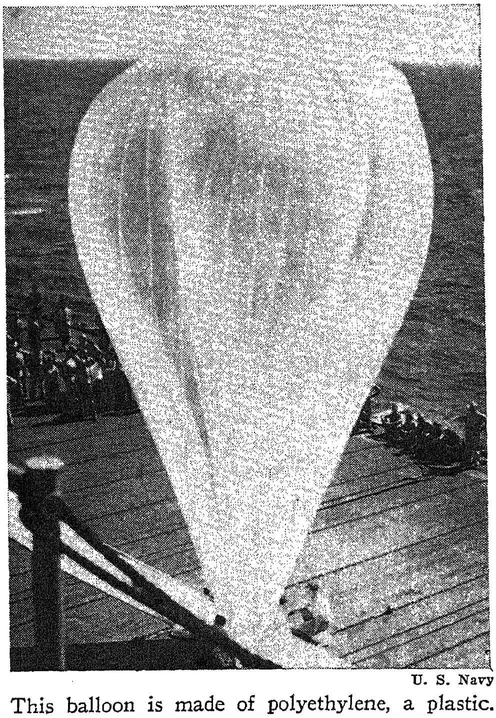
Link Aviation, Inc.

The Link jet trainer, designed to train the men who are to fly high-speed jet planes. This electronic device trains prospective flight engineers and radio navigators as well as pilots. It contains all the controls and instruments of a modern jet plane and operates just as the plane would do in actual flight. The apprentice flyer is in the cockpit. Sitting behind the cockpit is an instructor; he has before him an additional set of controls with which he introduces emergencies that come up in flight.



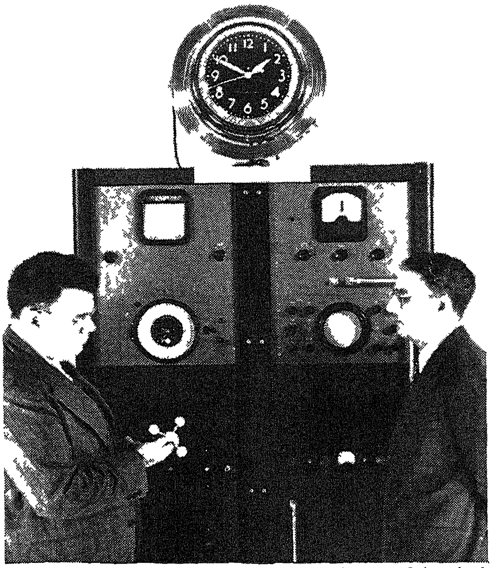
Department of Defense

A fire-fighting suit of aluminum foil on cloth.



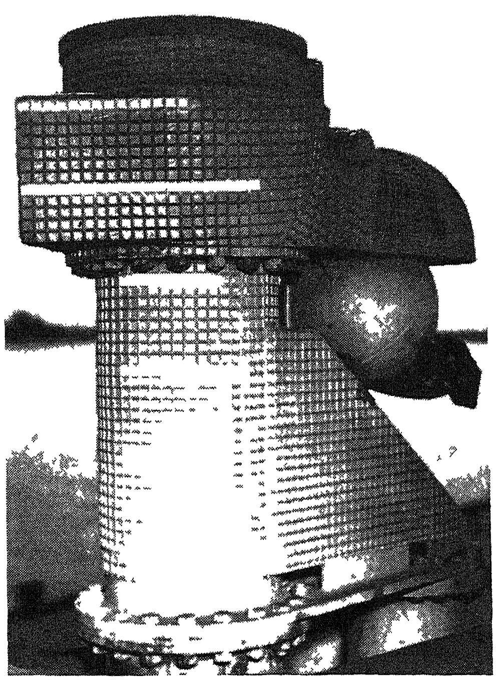
U. S. Navy

This balloon is made of polyethylene, a plastic.



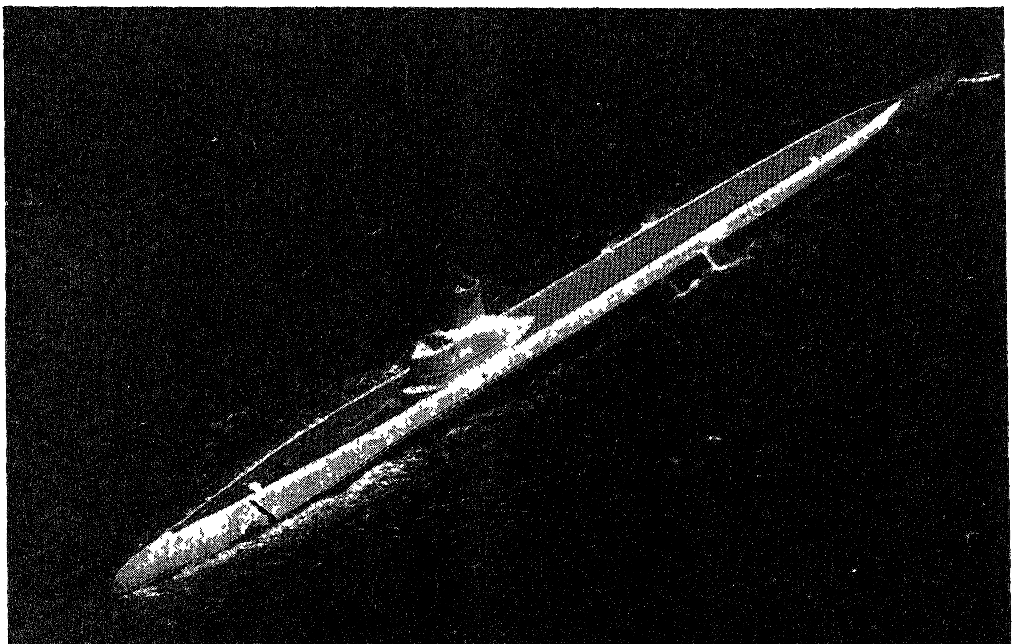
National Bureau of Standards

This atomic clock was developed by the U S. National Bureau of Standards. It is based on a constant natural frequency — the vibration of atoms in the ammonia molecule. This vibration is transmitted to an oscillator, which in turn is used to drive the clock. The atomic clock, an electronic contrivance, is far more accurate than the conventional clocks that record the time based on the earth's period of rotation. The earth's rotation varies. the atom's vibrations do not.



Right-hand and lower photos, U S Navy

A close-up of a schnorkel. This is a "breathing" device for submarines: it draws in fresh air, while foul air and engine exhaust pass out from it. The schnorkel has been very widely adopted



The U.S.S. Pomodon, a fine schnorkel-equipped submarine. Since the schnorkel draws out engine exhaust, the submarine is run by its Diesel engines while under water, instead of by its batteries. This increases under-water speed; besides, the submarine can remain submerged for weeks at a time.

RECENT PROGRESS IN MEDICINE AND SURGERY II

by

WARREN T. VAUGHAN, M.D.

Editor-in-Chief, Journal of Laboratory and Clinical Medicine

THE METHODS which have been devised to combat infection within the body have been quite varied. Those germs such as the diphtheria bacillus or tetanus bacillus which secrete poisons or toxins may be counteracted by the administration of an antitoxin. Others, as certain forms of pneumococci, may be combatted with an immune serum which tends to destroy the bacteria. The gonococcus, responsible for gonorrhea, and Treponema pallida, the germ causing syphilis, are both destroyed at high temperatures. Fever therapy in which the temperature of the human body is artificially raised to the neighborhood of 106 degrees is one of the measures used to combat these infections. Certain germs are poisoned with chemicals which are relatively harmless to the human being. Examples are quinine in malaria, arsphenamin for syphilis, emetin for amebiasis.

There remain a number of bacterial infections against which no effective vaccine, serum, chemical poison or other remedy has been found. One of these is the streptococcus.

In 1935, Gerhard Domagk of Germany, experimenting with streptococcus infection in mice, found that the hydrochloride of 4 sulfamido-2′, 4′ diamino azobenzene appeared to destroy the infection. This substance, the name of which has been officially abbreviated to sulfanilamide, is a byproduct of the anilin dye industry. The possibility of its success in the treatment of streptococcus infection was evident, and a few German, French, British and American investigators undertook studies to determine, first, whether it is safe to use in human illness and second, whether it held promise of being curative. The first American report by Long and Bliss of Johns Hopkins Medical School appeared in January 1937. Since then a large volume of laboratory and clinical investigation has been reported indicating that sulfanilamide is a valuable drug in certain forms of streptococcus infection and in certain other infections as well, and that, although it is not harmless, when properly used it is a reasonably safe drug.

Although investigations have not yet disclosed the exact manner of its action it appears at present to be directly germicidal, more poisonous to the germs growing in the body than to the body cells themselves and therefore usable, provided the dose is kept low enough so that the body cells are not simultaneously poisoned. Its action is not so much by killing the streptococcus as by slowing down the rate of their multiplication, thus permitting the phagocytes or white blood cells to engulf and destroy them.

There are several varieties of streptococci. Sulfanilamide is more effective with hemolytic streptococci than with non-hemolytic, and especially so with a variety termed *beta hemolytic streptococcus*. Streptococcus bloodstream infection and streptococcus meningitis are so uniformly fatal that any method of treatment which results in recovery, even of only a fair percentage of such victims, is an improvement over existing methods.

Other infections which have been found favorably affected are meningococcus meningitis, gonococcus infec-

tions, erysipelas (streptococcus) and gas gangrene. With sulfanilamide, the mortality from hemolytic streptococcus infection in the blood has been cut to about 20 per cent. The mortality in a series of cases with meningococcus meningitis treated with sulfanilamide was 15 per cent as compared with 30 per cent mortality among patients treated with antimeningococcus serum. The drug appears to be of little or no value in scarlet fever, another streptococcus disease.

The drug may be given by mouth or hypodermically and is excreted through the kidneys into the urine. It may, therefore, be used in the treatment of urinary tract infection provided the infecting germ is one which is susceptible to sulfanilamide action. Two such cases have been reported, in which the urinary tract infection was due to the influenza bacillus. The drug destroyed this infection. Since, if it is not excreted, continued administration would result in the accumulation of increasing amounts of the drug in the body, it is not given at the present time to cases with badly diseased kidneys.

A curious phenomenon usually accompanies sulfanilamide treatment: an intense cyanosis or bluish discoloration of the mucous membranes, less so of the skin, which appears not to be due to absence of oxygen in the blood, change of hemoglobin to methemoglobin, or sulphemoglobin,—the three common causes for cyanosis. The cause is unknown and the discoloration of the blood appears not to be harmful.

It has been observed that the drug becomes poisonous when given with other drugs containing sulfate. This calls for considerable caution since common drugs such as magnesium sulfate (Epsom salts) might be taken at the same time without the physician's knowledge. It has been felt safer to give no other drug with sulfanilamide, except sodium bicarbonate when needed.

As stated above, sulfanilamide is of value because it is more harmful to the germ cells than to body cells. In common with many other drugs, it does possess a degree of toxicity for the tissues of the patient. For direct poisonous action, however, a much larger dose is required than is used in treatment. However, it has been found that a rather high proportion of patients (about 15 per cent) develop an idiosyncrasy to the drug, becoming sensitized or allergic. After this has occurred, sulfanilamide becomes harmful (to the 15 per cent) and can no longer be used with safety. The characteristic manifestation of beginning sensitization in patients who have been taking the drug each day for many days consists of high fever, and urticaria or hives or a measles-like eruption, with itching. Such reactions are well known with other drugs and are called drug fever and drug rash. When they occur they usually appear about a week after treatment has been begun and indicate the onset of sensitization. The reaction is analagous to serum sickness whch occurs about a week after the administration of therapeutic serum and presents very much the same symptoms.

Occasional patients develop much more serious allergic reactions, such as purpura (subcutaneous hemorrhages), a scarlet fever type of eruption, exfoliative dermatitis (severe generalized skin inflammation), agranulocytosis (disappearance of the protective white blood cells from the blood.

Among sulfonamide compounds recently developed are: sulfathiazole, effective against staphylococcus infections; sulfanilylguanidine, effective in intestinal infections; sulfapyridine, effective against pneumococci; and sulfadiazine, which has been found superior to sulfanilamide and sulfapyridine because it will control any kind of infection and cause a lesser amount of toxic reactions.

Dementia Precox

Dementia Precox is a form of insanity for which there is no specific cure. Known technically as schizophrenia ("a split or divided mind"), the disease is not common, attacking about one-third

or two-thirds of 1 per cent of the population. However, it is responsible for one-fourth of all cases of insanity in mental hospitals. There are over 400,000 hospitalized insane in the United States, from 80,000 to 100,000 of whom suffer from schizophrenia.

The disease is not necessarily incurable. Although there is no specific treatment, from 20 to 40 per cent of such patients, properly cared for by physicians skilled in the treatment of mental disease, recover sufficiently to return to a normal mode of living even though the tendency to recurrence of the disease persists.

In 1933, Dr. Manfred Sakel of Vienna, introduced a new method of treatment in which the essential feature was the repeated production in the patient of coma or unconsciousness by means of large doses of insulin, the drug used in the treatment of diabetes. With this method he obtained full remissions in 70 per cent and in an additional 18 per cent the patients improved to a point where they could return home and carry on their work. Other European investigators later reported similar good results. In 1937, a number of psychiatrists in the United States undertook this new treatment. While the majority did not report as good results as Sakel, it should be borne in mind that the cases treated were fewer and that greater experience with the method may produce better results. In 1944 this treatment was recommended for patients in New York State Hospitals for the Insane.

Treatment consists in the induction of insulin shock daily for a rather long period. It appears that the frame of mind in which the patient emerges following unconsciousness tends to persist. The physician is able to control this in some measure. Best results have been obtained in early cases in which insanity has been of short duration.

Since there is no clearly defined physiologic reason why this treatment should be beneficial; since a certain proportion experience remissions without any treatment; and in view of the fact that a number of years must elapse before it can be determined that the cure is permanent, insulin treatment of dementia precox must be accepted as promising but not established.

Pellagra and Nicotinic Acid

Pellagra is a disease of both the new and old worlds. In the United States it has affected chiefly the poor and undernourished farmers of the Southern States

Courtesy Health and Hygiene
DR. JOSEPH GOLDBERGER

whose diet has consisted mostly of salt pork, molasses and corn meal mush. Elsewhere it has been chiefly a disease of chronic alcoholics whose resultant indigestion has prevented their receiving adequate nourishment. Several years ago the late Dr. Joseph Goldberger of the United States Public Health Service, established that pellagra is a deficiency disease probably due to the absence of a special vitamin, a pellagra preventing vitamin, which he termed P-P factor or vitamin G. He found that the feeding of fresh meat, liver, fresh vegetables, milk and yeast was effective in preventing pellagra and assumed that the vitamin was contained in these substances.

Vitamin studies later indicated that vitamin B, the food principle that prevents beriberi and peripheral neuritis is probably not a single vitamin but is a

combination of two or more and it was therefore termed "vitamin B complex." The antineuritis factor was designated B-1 while the P-P factor, or the former vitamin G, was found to be of the vitamin B complex and was designated vitamin B-2. From their action it appears that they are two distinct food principles but they usually occur together in the same food substances and they are therefore classed together as B complex.

Goldberger, before his death, succeeded in reproducing a disease of dogs known as blacktongue following the feeding of the same diet that he had found would produce pellagra in human beings. Fortunately, therefore, an experimental animal was available for study of possible curative agents for pellagra.

A series of reports all appearing in the last four months of 1937 makes it probable that the elusive vitamin B-2 has been isolated, purified, identified and that its effectiveness in the treatment of pellagra will be proven.

As stated above, liver contains the pellagra preventive factor. Two authors, Mueller and Subbarow of Boston, isolated nicotinic acid from the liver. Elvihjem and his associates from Wisconsin also obtained nicotinic acid from the liver and proved that it was curative of blacktongue. Others confirmed this observation and nicotinic acid is now being used in the treatment of the blacktongue that occurs naturally in dogs. Smith, Ruffin and Smith of Duke University next gave nicotinic acid to a patient with far advanced pellagra who was kept during the period of the experiment on a diet which would produce pellagra. Following daily administration of the drug, either by mouth or into the muscles or directly into the veins, the patient cleared up almost entirely within twelve days. The extensive skin eruption and his dementia cleared up entirely.

Nicotinic acid is very cheap. The entire cost of the drug used in the treatment of this case was ten cents. It could therefore be made readily available for those poor persons who up to the present have had to live on an inadequate diet. It has been isolated in pure crystalline form as nicotinic acid amide. It appears to be present in plant and animal tissues and in tobacco. There is evidence that it is an essential constituent of one of the enzymes or ferments of the body which facilitates transfer of oxygen from the red blood cells to the cells of the tissues.

It seems probable that nicotinic acid or nicotinic acid amide or some closely related compound will be established as the vitamin B-2.

Pneumonia

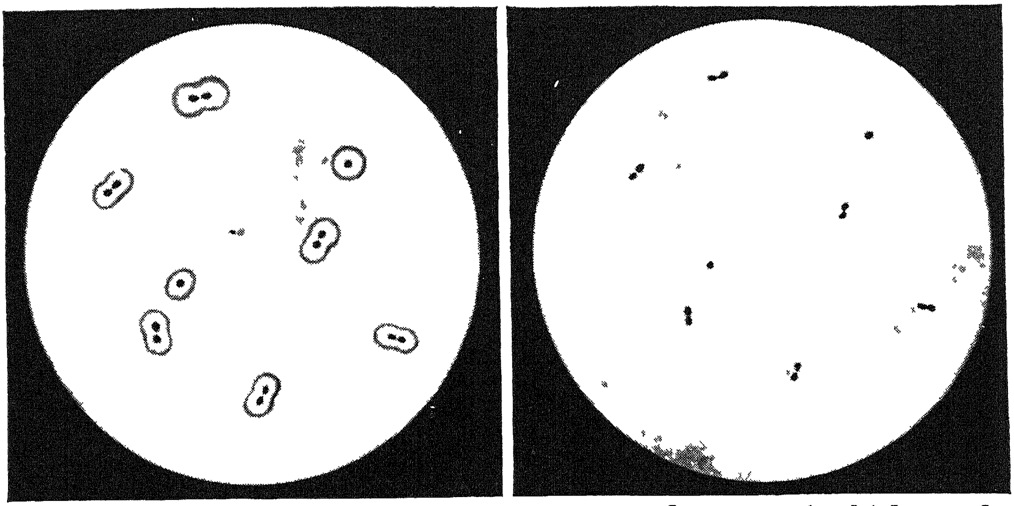
It has been estimated that in New York City alone there are 26,000 cases of lobar pneumonia per annum. Since the death rate is about 25 per cent, pneumonia becomes a disease of great importance.

The pneumococcus was proven to be the cause of lobar pneumonia as early as 1886. It is responsible for well over 90 per cent of all cases. In 1909 it was shown that there are several different types of pneumococcus, that all of these germs which appear to be very much alike under the microscope are not the same. Pneumococci were at first divided into four types. Type I was found to be the most frequent cause and Types I, II, and III together caused about 80 per cent of pneumococcus pneumonia. Group IV is not a single type but represents a large number of specific types which were originally grouped together because there was no immune serum available for any of them and because they seemed to be rare causes of pneumonia. Beginning in 1926 investigation of the individual members of Group IV was undertaken. To date it has been established that there are 32 different types of pneumococcus. Immune serum used in the treatment of pneumonia must correspond to the type of pneumococcus causing the disease in a given individual. Thus if one has a Type II pneumococcus infection he must be given serum from horses which have been immunized

against Type II pneumococcus. Type I serum will be of no value. Some types when injected into horses produce powerful immune serums which may be used in treatment while others do not. Up to the present potent serums are available for Types I, II, V, VII, VIII and XIV.

Serum treatment of pneumonia was started by Cole at the Rockefeller Institute in 1913. At that time he and his collaborators found that Type I serum was very effective, reducing the death rate from over 30 per cent to about 10 per cent. Types II and III sera which were then available were of little value in Types II and III infection. However, in 1924 Felton of Harvard developed a method for concentrating the serum, thereby both purifying it and making it more potent. Concentrated sera are now available for the various types mentioned above and for experimental use with other types and have demonstrated their effectiveness in reducing the mortality and the incidence of complications in lobar pneumonia.

Although in the approximately twenty-five years since serum treatment was first attempted the improvements enumerated have resulted in the final production of a powerful remedy for the disease, serum treatment is still not widely used. There are several reasons. To be effective, serum must be given early, certainly within the first four days of pneumonia. The appropriate type serum must be administered. The determination of the type of pneumococcus infection originally required from twelve to twenty-four hours. Often this was not started until the patient had been sick for several days. Sometimes this was because the diagnosis was uncertain during the first few days, at other times because the physician was not called early enough. Today, with improved methods, the type determination may be made within an hour. A very great drawback has been the matter of expense. The cost of serum alone, for the treatment of a case of lobar pneumonia ranges from $100 to $150. With material as expensive as this, few establishments were able to keep it on hand in adequate quantities. As a consequence, once the type was determined it was necessary to

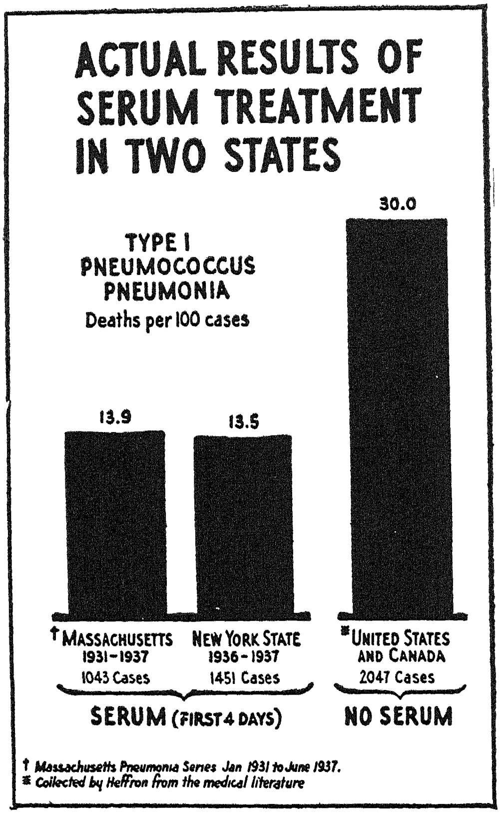


Courtesy Metropolitan Life Insurance Co.

DETERMINATION OF PNEUMOCOCCUS TYPE BY THE NEUFELD METHOD

THIS MICROPHOTOGRAPH SHOWS THE APPEARANCE OF A POSITIVE REACTION INDICATED BY THE SWELLING OF THE CAPSULES OF THE PNEUMOCOCCI THE TIME REQUIRED FOR THIS TEST IS FROM FIVE TO THIRTY MINUTES

THIS MICROPHOTOGRAPH SHOWS THE APPEARANCE OF A NEGATIVE REACTION THE CAPSULES OF THE PNEUMOCOCCI ARE NOT SWOLLEN EFFECTIVE SERUM TREATMENT OF PNEUMONIA DEPENDS UPON ACCURATE TYPE DETERMINATION



Courtesy Metropolitan Life Insurance Co.

wire to some remote pharmaceutical supply house for the serum to be sent by mail or by plane. All of this required time and by the time serum treatment was at last started it was often too late to do much good.

Realizing the importance of serum treatment in appropriate cases, the health authorities of New York, Massachusetts and Michigan undertook the preparation of immune sera and established testing stations for type determination, with supply depots for serum at widely scattered points throughout the states where physicians have the advantage of expert laboratory consultation and the use of serum.

Penicillin and Vivicillin

The therapeutic values of penicillin, a mold extract discovered by Fleming in London in 1929, were revealed in 1940 by Florey, Chain, and others. Potency is expressed in Oxford units. It is used to treat certain staphylococcal, streptococcal, and pneumococcal infections. It is given by injection into the veins and muscles and may be applied locally.

Courtesy Commercial Solvents Corporation

RABBITS USED IN THE PYROGEN TEST FOR PENICILLIN

In 1944, vivicillin, a derivative of penicillin, discovered by the German scientists, Enoch and Wallensteiner, was announced. It was reported effective in the treatment of peritonitis, mastoiditis, and for septic wounds.

Investigators at The Rockefeller Institute established that rabbits could be immunized successfully against the same types of pneumococcus as horses. They found unconcentrated rabbit serum to be as effective in treatment as concentrated horse serum, possibly more so. The cost of preparation of this rabbit serum is far below that of concentrated horse serum.

Operation upon the heart

Advances in surgery during the last fifty years, even the last twenty-five years have been truly remarkable. In the days before bacteriology. when infection could not be controlled, operations were usually performed only of necessity as a lifesaving matter. Today we speak of operations of election, where surgery is not a procedure of last resort but may even be applied to relatively well persons, purely for the relief of some more or less annoying distress. Operations within the abdomen represent the earlier surgery of election. But with improved technical methods and a clearer understanding of the physiology of the body it has been possible to enter regions where formerly the procedure would have spelled death. Now the lobe of a lung, even an entire lung is removed for cancer or infection. Even the half of the brain, the cerebrum, has been removed for tumor without fatality, although the patient necessarily remains paralyzed on one side. Within the last few years the surgeon has even invaded the heart, sometimes with success.

The heart is about the size of one's fist and is suspended in an envelope, the pericardium, very much as one's fist may fill an old-fashioned mitten without the thumb. It is attached only at the top, corresponding in the simile, to the wrist. The heart fills the pericardial sac completely, there being just a thin film of fluid between it and the outer envelope. This fluid serves as a lubricant to prevent friction as the organ contracts and expands during the heart beat.

Occasionally the lining cells of the envelope become inflamed, usually due to local bacterial infection. This is pericarditis. When such a condition exists, fluid accumulates in the sac thereby tending to compress the heart and embarrass it in its movement. Sometimes this pericardial effusion must be drained off through a needle. After healing of pericarditis, when the fluid has been reabsorbed and the two inflamed surfaces, the envelope and the surface of the heart itself return into contact and rub together, adhesions may form. The adhesions may be few or may be so extensive as practically to obliterate the entire space between the heart and its surrounding envelope. The end result is known as adhesive pericarditis.

In the presence of adhesive pericarditis, each time the heart contracts, it has double duty to perform. It must not only do its normal work of pumping the blood through into the vessels but it must also pull against the resistance of the pericardium and surrounding tissues, in order to contract. This it does with more or less success for a time, but it soon fatigues and the patient develops edema or swelling of the legs and abdomen, due to ineffective circulation of the blood.

Surgeons are now able to give partial relief by one or both of two procedures. In adhesive pericarditis the heart is tugging against the chest wall. Several of the ribs in front of the heart may be removed, thus lessening the resistance against the tug. The other procedure consists of actually opening up the pericardial sac, breaking up the adhesions and removing the infected layer from the surface of the heart.

The operation is not totally curative since too much damage has already occurred and the mortality from the oper-

ation itself is high, but in a fair proportion many months of comfort are added to the life of a person who otherwise would be a hopeless invalid.

Leprosy

This is undoubtedly an ancient disease. It is mentioned in the first chapter of Exodus. It was one of the three signs by which God proved to Moses that He was Almighty. However, modern research has indicated that the Biblical leprosy was probably another disease. True leprosy was known by the ancient Chinese, Indians and Egyptians and was probably introduced into Greece three or four hundred years before Christ. By the 7th century A.D. it was quite prevalent in Southern Europe. It was introduced into England about 950. Today it is rather widely distributed in subtropical and tropical countries. In 1935, McKinley estimated that there were nearly one and one-half million lepers in the world. The germ causing leprosy was first described by Hansen in 1874. It resembles the tubercle bacillus somewhat in appearance and was found growing in the tissues involved in leprosy. Several investigators have since claimed to have grown the leprosy bacillus in the laboratory, but McKinley, who has made a very comprehensive survey of the literature and has, with Soule, done a large amount of investigative work himself, believes that the germ has never heretofore been cultivated, that those germs which were grown in the laboratory were contaminations. A few years ago McKinley of George Washington University and Soule of the University of Michigan succeeded, with very technical methods, in growing a different germ in test-tubes, which they believed to be the leprosy bacillus.

In order to prove that any germ obtained from the tissues of a patient with leprosy and grown in the laboratory is the cause of the disease, one should be able to produce leprosy by inoculation of the laboratory material into a nonleprous person. This has never been accomplished with any of the germs that have been cultivated. McKinley in 1937 therefore undertook another procedure by which indirect evidence might be obtained. Taking a large quantity of his laboratory material to the Philippine Islands where there is considerable leprosy he proceeded to make skin tests with an extract of his bacterium, testing lepers and nonlepers. If his germ is the cause of leprosy, lepers should give positive skin reactions to the extract while nonlepers should not.

Before his death, McKinley obtained suggestive but not as yet conclusive evidence in the Philippines.

It is important that the true germ of leprosy be discovered and that there be facilities for the infection and experimental treatment of laboratory animals, so that the information gained may be applied in the treatment and cure of human lepers. It is therefore hoped that McKinley's work will be brought to definite conclusions.

Leprosy, although contagious, is not a highly contagious disease, and there is every probability that as soon as successful laboratory work is done the cure will be forthcoming. It is not a filth disease as was thought in ancient times.

RADIUM IN THE FAR NORTH

by

BORIS PREJEL

President, Canadian Radium & Uranium Corporation

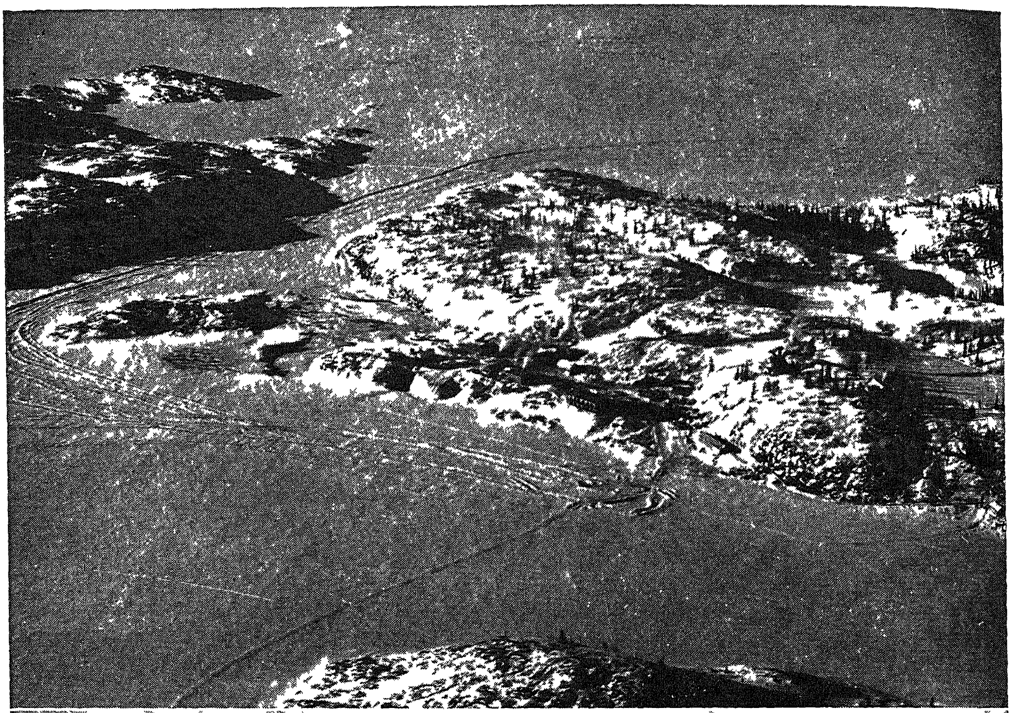
THE discovery of radium-bearing ores in the Great Bear Lake area of northern Canada attracted world-wide attention, not only because of the importance of radium to the world, but also because of the remoteness of the deposit from all transportation. Could a mine be developed on the edge of the Arctic Circle, separated by thousands of miles of rocky wastelands from a commercial center? The answer has been given, largely owing to the development of airplane and water transportation serving these new areas.

Radium, because of its rarity, is the most precious of all metals, its value being reported (1943) as from $25,000 to $30,000 per gram. Prior to the discovery of the silver-pitchblende deposits in northwestern Canada, when production was confined to certain silver mines of Czechoslovakia and the carnotite ores of Colorado, it was even more expensive. Its value was $125,000 a gram in 1912, and later, following the discovery of pitchblende in the Belgian Congo, the price fell to $70,000 per gram.

In 1930 a Canadian prospector, while investigating cobalt-bloom stained rocks, discovered a vein of pitchblende. Samples were collected and sent to the Canadian Department of Mines and Resources, who determined the uranium-radium content as being unusually high. Later exploratory and development work showed the deposit to be large. Undaunted by the fact that the deposit was located almost on the Arctic Circle,

Courtesy *The Northern Miner*
An airplane equipped with skis lands necessary supplies in winter. A heater under the blanket helps warm the engine.

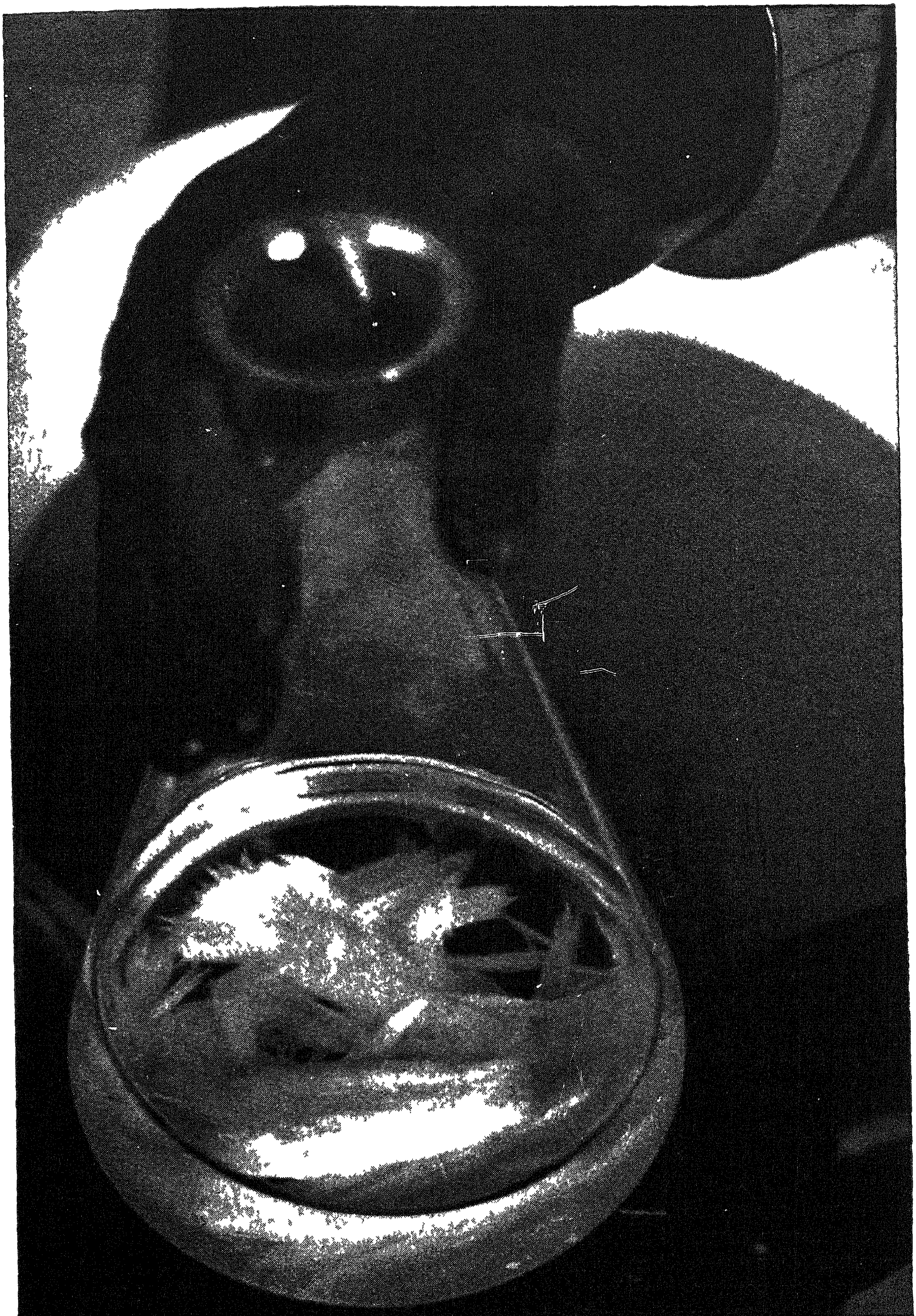
RADIUM AREA AT GREAT BEAR LAKE



Courtesy *Associated Screen News Ltd*

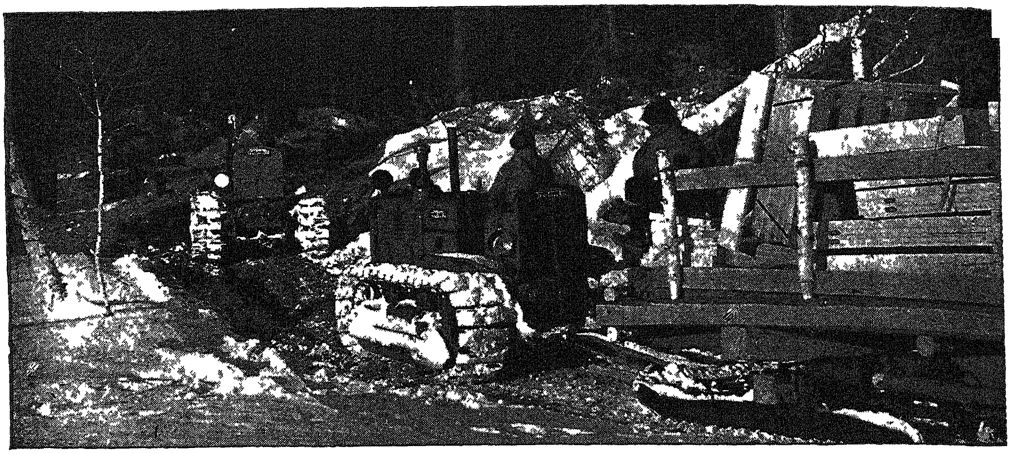
Above, LaBine Point, N W T looking into Echo Bay Buildings shown are a part of those used for mining and concentrating the radium bearing ore Below one mode of transportation in the Great Bear Lake area

A FORTUNE IN A FLASK



Courtesy *Associated Screen News Ltd*

Shown in the flask are crystals of radium barium bromide during the final stages of fractional crystallization



Courtesy *The Northern Miner*

Tractors provide winter transportation over the frozen lands and the ice covered lakes and rivers These tractor trains never stop, but plod along day and night carrying heavy freight between mine and railroad

plans were laid for its commercial development. Today the deposit is the site of modern mining camps, and is the source of largest production. The area which is situated 1,140 miles by air from Edmonton and 1,450 miles by water from Waterways, the end of rail transportation, is now fully developed.

Although some of the concentrates in the early years were transported by airplane to the railhead 1,000 miles away, most of this material is now handled by lake and river boat 1,500 miles to the railway and thence 2,500 miles to the nearest refinery. Navigation, however, on Great Bear Lake is open for only one and one-half months of the year, although on the Mackenzie and Athabaska rivers the season of open water is four months. There is only a very short period, therefore, when supplies may be taken in or out.

Geology and Mining

The veins containing the pitchblende-silver ore are found in sheared and fractured zones in the surrounding greenstone rocks. Lack of overburden and scantiness of vegetation leave rock exposures that are visible for miles and the fractured zones traversing the ridge at LaBine Point are easily seen from the air. The larger zones have a length of at least 4,000 feet, and are from four to ten feet wide.

Pitchblende, or uranium oxide, occurs both in the massive and botryoidal, or kidney form. The radium has been found to occur in a constant ratio of between two and three milligrams of radium to every twenty pounds of uranium oxide or roughly 1 to 3,470,000, and this ratio holds good wherever radium is found.

In a geological sense, one may say that the region has only just emerged from the glacial period and permanent frost, resulting from the continental ice cap which covered the surface for thousands of years.

In this wasteland arose model mining camps, in which plant buildings and workmen's quarters are provided with steam heat, running water, and electric light. Resident doctors watch over the health of the mining staffs and since the beginning of operations no employee has shown any ill effects from either dust or radium emanation. All supplies including food are shipped in from outside during the navigation season. During the winter fresh fruit and meat are flown in by plane.

Milling

Wherever possible the high grade pitchblende is sorted by hand in the stopes and sent directly to the surface where it is bagged for shipment to the refinery.

Courtesy *The Northern Miner*

During the summer freight from Great Bear Lake is carried by the *Radium King* to Fort Smith Here the freight is hauled overland to the *Radium Queen* which carries it to the railroad at Waterways.

Pitchblende cannot be recovered by ordinary flotation methods. Moreover, because of its tendency to slime during grinding, it must be removed from the grinding circuit as soon as possible. For this reason gravity methods of tabling and jigging are used in present-day milling practice.

Extraction

The recovery of the radium from the pitchblende ores presents a complex and difficult problem. Quite apart from the infinitesimal amount present even in this rich ore, there is the terrible hazard arising from handling radium even in

comparatively small concentrations. No ordinary metallurgical process is suitable, and the process as finally evolved is a chemical one involving large-scale laboratory operations. Every ton of pitchblende requires six tons of chemicals, and some thirty or more different steps are required for the production of the radium barium salts.

Briefly, the process consists of four different major operations: (1) roasting and milling; (2) separation of uranium, recovery of silver, and the production of radium barium sulphate; (3) production of radium in laboratory; and (4) recovery and refining of uranium salts.

To avoid the loss of the pinch of radium present in tons of ore some barium is added to it, until the barium content is 500,000 times that of the radium. Barium, having a powerful physical affinity for radium, gathers into its bosom every last atom of radium and hugs it tight. When all is gone but the barium and the radium in its custody, an odd new problem presents itself. Barium and radium, so much alike chemically, cannot be separated by chemical means. Even in building crystals, they act jointly. It so happens, however, that radium salts are somewhat less soluble than barium. And so, by long series of fractional crystallizations, starting in an open-pan elevator and ending in a thimble-sized vessel, the radium is eased out 90 per cent pure, that is, nine parts of radium salt to one part of neutral barium salt.

Practical applications of radium

Radium has several important practical applications as a spontaneous source of remarkable radiations. These radiations are produced by the disintegration of radium, but this disintegration is so slow that it requires about 1600 years for the disappearance of half of any amount of radium. The useful gamma-radiation is not produced by radium itself, but its disintegration products, the first of which, radium emanation or radon, is a gas. In a sealed container this gas accumulates until the rate of its decay equals the rate of its production (after about one month).

The gamma rays from radium products, which are similar to X rays, but still more penetrating, are used effectively in the treatment of cancer. They are also extensively used for industrial radiography to detect internal imperfections in thick metallic castings or welds.

The apparatus necessary for industrial radiography is extremely simple. A small container of radium sulphate is sufficient to obtain, in a few hours, radiographs of castings up to ten inches thick; its price is that of a small yet voluminous X-ray unit unable to perform the same services. Radium has practically no wear and requires no maintenance. It requires no power from without, and can be worked continuously day and night with no personnel to operate or to watch it.

Another application of radium, very important in time of war, are the self-luminous paints, made with phosphorescent zinc sulphide in which a radium salt is incorporated. The alpha rays from radium, and from its disintegration products, excite in this substance a permanent glow completely independent of any previous illumination. Such luminous pigments found extensive use for airplane and warship control dials in World War II.

THE MIRACLE OF ICE FROM HEAT

How a Tiny Flame Keeps Food Fresh in a Refrigerator

by

WILLIAM T. HEDLUND

(Illustrations and text authorized by special permission of Servel, Inc.)

YEARS AGO, when gas refrigeration was first being introduced, an ingenious hostess remarked, in the course of a discussion on the subject of magic, that she could produce ice by means of heat. When the guests' amazement that anyone possessed such magical powers had given way to doubt, the hostess asked them to come to the kitchen where she proudly exhibited her gas refrigerator. The doubting guests were astonished but convinced, for truly enough, a small flame was the agent employed to produce ice.

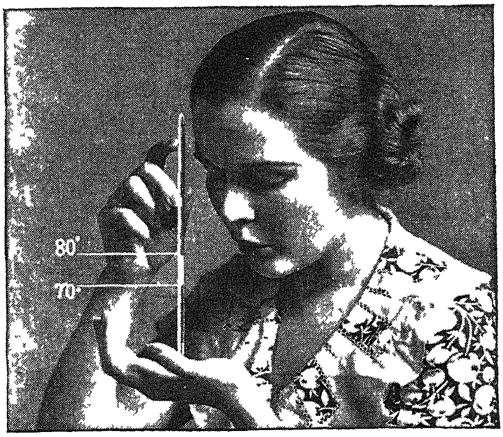
Though today, with the widespread use of gas refrigeration, the fact that heat can be used to produce cold is no longer surprizing, nevertheless considerable interest centers around the means by which this apparent miracle is accomplished.

The original Electrolux refrigerator, since developed into the Servel Gas Refrigerator, was invented by two students at the Royal Institute of Technology in Stockholm, Sweden, Baltzar von Platen and Carl G. Munters. You might expect that so unusual a device would be difficult to understand. However, it does not require a technical mind to understand how cold can be produced from heat alone.

A simple experiment in refrigeration

Pour some alcohol (rubbing or wood alcohol will do) on the back of your hand. Blow on the alcohol. This spot will feel real cool. Now blow on your other hand where there is no alcohol. It will not feel cool.

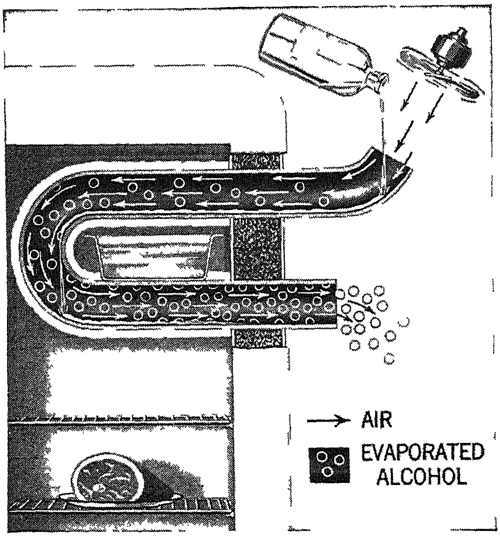
What happened when you blew on the alcohol? Liquid alcohol was swept by a stream of warm air and the result was a temperature below the temperature of either the alcohol or the air. In reality this simple process produced refrigeration.



As alcohol evaporates it forms a gas mixture of air and alcohol just above the liquid. If this gas mixture is blown away so that more alcohol can evaporate freely, considerable cooling can be produced.

As the air sweeps past the hand, the alcohol disappears. It evaporates into the air. Cold can be produced by evaporation of a liquid. You proved this by blowing on the hand that had alcohol on it. You could feel the cold.

You will be surprised how much cold can be produced in this way. Pour some alcohol in the hollow of your hand and place a thermometer bulb in the liquid. Then as you blow on the alcohol watch



Evaporation can take place in a pipe by letting alcohol trickle down the pipe while a slow breeze of air passes over the liquid alcohol Such a pipe is an "evaporator" If the evaporator is placed in an insulated enclosure we have a simple refrigerator

how quickly the mercury drops. If you could blow continuously and had a continuous supply of alcohol poured into your hand, you would be producing continuous refrigeration.

Evaporation is used by nature to cool the human body. The body has pores or moisture outlets. Normal body temperature is 98 6°F. If the atmosphere is appreciably cooler, the heat continuously generated by the body is readily dissipated. However, the body may produce heat faster than it is dissipated in normal manner. Nature then comes to our assistance by producing body moisture (perspiration) and evaporation of body moisture. The evaporation of the moisture (water) into the air takes heat from the body and the removal of heat is a cooling effect. An intense chill may be felt if your perspire and stand in a breeze.

The foregoing facts applied to make a simple refrigerator

We have seen that evaporation can produce a cooling effect. How can we use this evaporative cooling effect in a refrigerator box? We need a supply of alcohol and a flow of air. Of course the alcohol should not evaporate directly into the air in the refrigerator. Flow suggests pipes. So let us run an ordinary metal pipe through the box and have the alcohol and air flow through the pipe. A metal pipe is a good conductor Consequently the cold produced by evaporation in the pipe is directly used to refrigerate the contents of the box.

So we place a loop of pipe in the box and pass the ends through the insulation of the box. If we pour liquid alcohol into the pipe so that it flows down through the pipe, and if we pass a current of air through the pipe, we will have evaporation within the pipe and the box will be refrigerated. As the alcohol evaporates into the air, a gaseous mixture of alcohol vapor and air is formed in the same way as when you blew on the alcohol in your hand. We have made a simple refrigerator. If we now place a tray containing water on the pipe, we can produce ice.

The evaporator is the part of the refrigerating "system" which is inside the refrigerator box. There are other parts to the system, but they are outside the insulated food space. They serve to make the process continuous, automatic and economical.

The evaporator of the Servel Gas refrigerator is made up of a number of loops of pipe arranged in the walls of a "chest" for ice drawers and also exposed to cool the food space directly.

Reclaiming the evaporated liquid

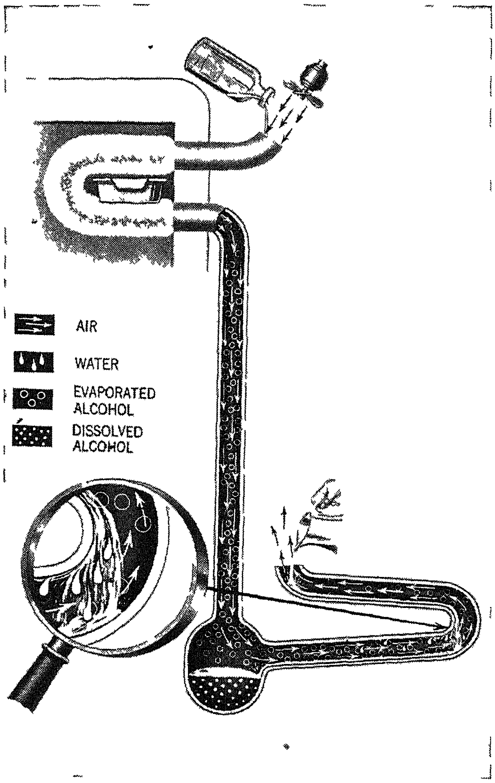
A mixture of alcohol vapor and air leaves our experimental evaporator. If we are to use the alcohol over again, we must first separate it from the air. This is easily done if we dissolve the alcohol in water. We know that water dissolves alcohol but does not dissolve air. A rain shower clears the air—actually washes it—but does not dissolve the air.

So let us sprinkle water into the mixture of alcohol and air leaving the evaporator. The shower of water washes the alcohol out of the air and the alcohol becomes dissolved in the water.

This is what is known as "absorption"

and it is for this reason that this system is sometimes called an "absorption type" refrigerator. Since we are adding the absorption step to save the alcohol, we will collect the water with the alcohol dissolved in it in a "bowl" or reservoir. The bowl is a part of the "absorber."

For simplicity, we can use another pipe of this absorption, with the "bowl" connected at the lower end of the absorber pipe. Of course, we must connect our new pipe and "bowl" to the evaporator. If we make this connection to the "bowl," the mixture of alcohol vapor and air coming from the evaporator will flow up in the absorber; while the water flows down. This "counter-flow" gives a good absorption.

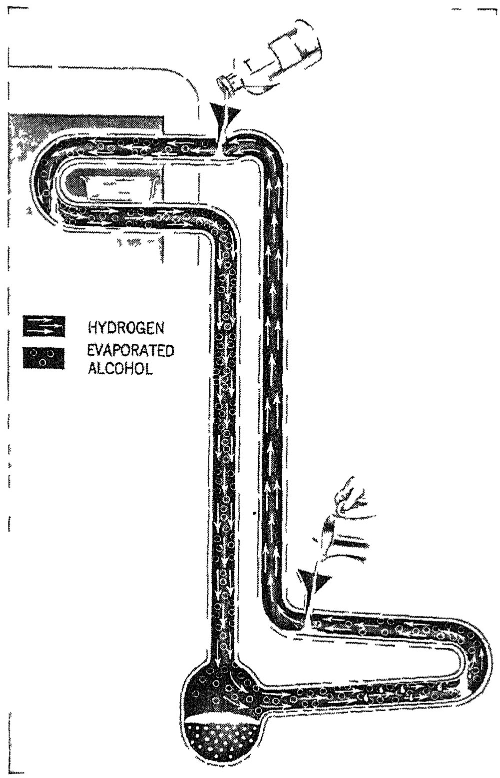


We "wash" the alcohol out of the air by means of water which dissolves the alcohol The water flows downward against the upflowing air in the absorber pipe The dissolved alcohol is collected at the bottom of the absorber

When the air reaches the top of the absorber, alcohol has been washed out of the air. When the water reaches the bottom of the absorber, it has absorbed alcohol. We have now segregated the alcohol from the air and have the alcohol in a readily usable form for reclamation.

The evaporator-absorber circuit

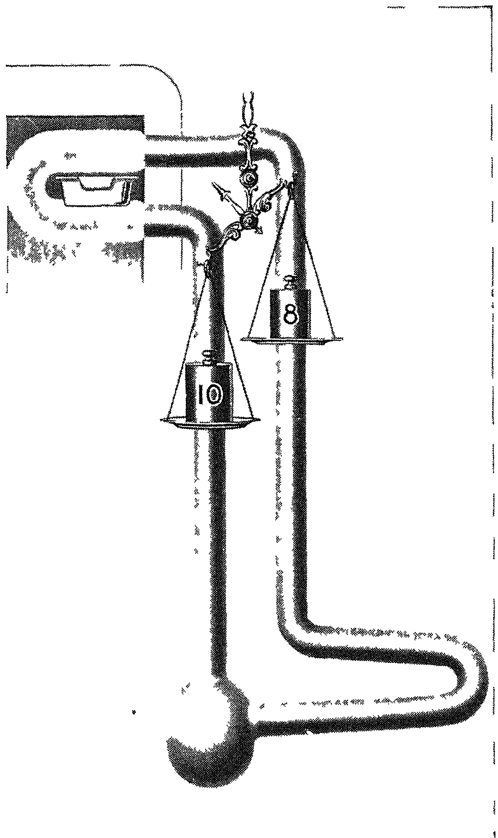
So far we have used air as the "gas" into which the alcohol evaporates. We could use other gases. The lighter the gas, the easier the alcohol evaporates into it. Hydrogen is the lightest gas and, at the same time, is not soluble in water and does not rust metal Let us change from air to hydrogen and blow hydrogen through the evaporator and into the absorber, just as we did with the air. The action will be the same.



Circulation is produced downwardly from the evaporator to the absorber and upwardly from the absorber to the evaporator solely by weight differences in the branches of the circuit

When we used air, which costs nothing, we could let it escape from the top of the absorber. But when we use hydrogen, we cannot afford to waste it

When it reaches the top of the absorber, alcohol has been removed and the hydrogen can therefore be used again. So let us close the top of the absorber, leaving an inlet for the water, and connect a pipe from the top of the absorber to the top of the evaporator, so the hydrogen can pass back to the evaporator.



The circulating force is analogous to difference in weights on a balance scale The preponderance of weight on one side makes the gas go down on that side and up on the other.

We have now made a circuit for the hydrogen through the evaporator, from the evaporator down to the absorber, up through the absorber and back to the evaporator.

When we used air it was easy to produce a "breeze." Even our lungs could provide the motive power. But, of course, when we change to hydrogen and close the circuit, we must supply some other force for producing a flow around the circuit.

It might be thought that a fan could produce the breeze of hydrogen. But we can apply a natural circulating force and eliminate moving parts because we have different gas conditions in different parts of the circuit. A mixture of alcohol vapor and hydrogen is heavier than hydrogen alone. As we have arranged the circuit, there are two vertical branches or columns; the heavier gas is in the down-flow pipe from the evaporator to the absorber and the lighter gas is in the up-flow pipe from the absorber to the evaporator. The heavier gas mixture produced in the evaporator therefore flows down by gravity and the lighter gas (the freed hydrogen) resulting from the absorption of the alcohol in the absorber must go up; just as the heavy side of a balance goes down and the light side goes up.

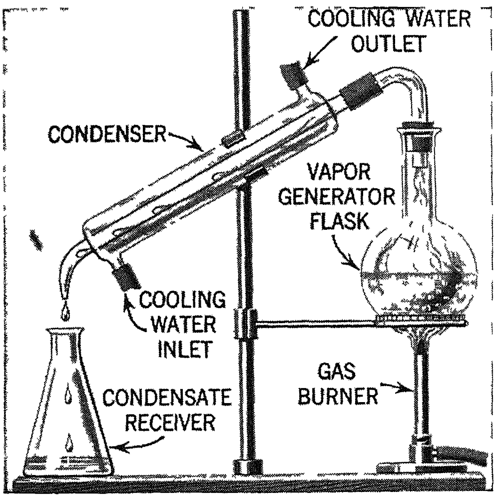
In effect, the heavy gas mixture flows by gravity from the evaporator through one pipe into the absorber and pushes the light hydrogen up in the absorber and back through the other pipe to the evaporator.

As long as we supply alcohol to the evaporator and water to the absorber, the heavy gas mixture is continuously formed in the evaporator and the lighter gas is continuously formed in the absorber. We therefore have continuous circulation, like a water wheel constantly supplied with water flowing down on one side and weighing that side down and flowing away at the bottom so that the other side is lighter.

In our case, the hydrogen gas is the wheel which goes round and round. The alcohol evaporating into the hydrogen weighs down the hydrogen to make one side of the circuit heavy. The other side is lighter because the alcohol is taken away at the bottom (in the absorber). The slow trickle of water in the absorber does not hinder the circulation. We now have a closed evaporator-absorber circuit continuously producing cold—without the use of a fan, pump, or other machinery.

We complete and close the system

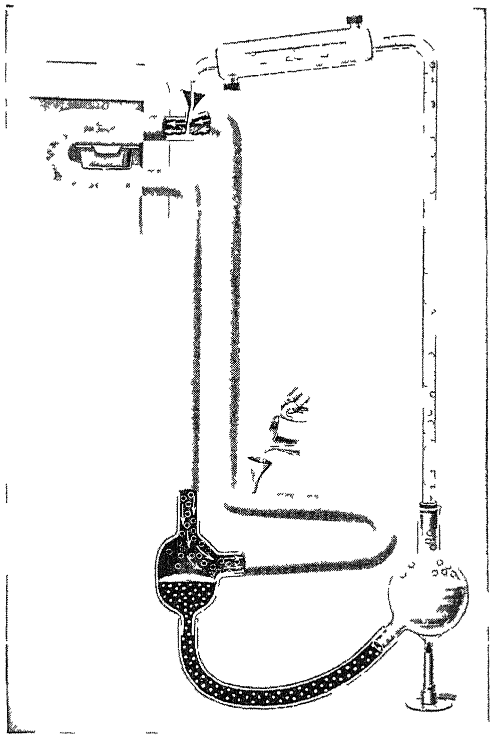
In the system so far built up, we have an outside supply of alcohol to the evaporator; we also have an outside supply of water to the absorber; and we are collecting alcohol dissolved in water at the bottom of the absorber. To make the system complete, we must separate the alcohol from the water; also, we must lift the separated alcohol and return it to the evaporator as a liquid; and we must lift the water and return it to the absorber.



A laboratory still Vapor is driven off and condenses in the condenser

An easy way to separate alcohol from water and liquefy the alcohol is to use a "still." This permits us to use heat alone and avoid moving parts. A still is a simple structure—a generator for vaporizing the substance to be distilled and a condenser connected to the generator to liquefy the vapor. We can use a very small still heated by a small burner. The alcohol is driven off as a vapor in the generator, leaving the water as a residue. Alcohol has a lower "boiling point" than water. The vapor, as we know, rises in the still and liquefies in the "worm" or condenser, and issues as a pure liquid. So, let us connect an ordinary still to the bottom of the absorber to receive the alcohol solution and connect the drip outlet of the still to the evaporator. We see that the evaporator becomes the receiver of the still. We have now completed the system, except for one thing: we have not raised the water so it can flow back into the absorber.

How shall we lift the water? Of course, we could use a mechanical pump, but that would require moving parts.

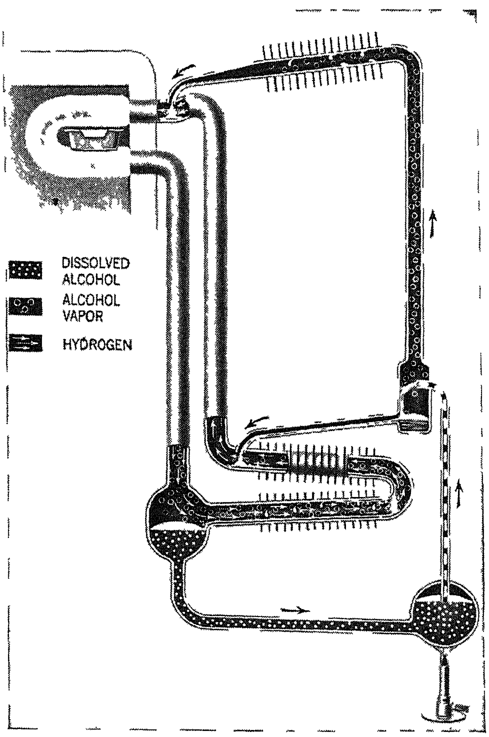


The alcohol is distilled from the solution and is liquefied in the condenser and flows into the evaporator

We do not want moving parts. What is there that lifts liquids without moving parts? We all know that a coffee percolator lifts liquid. Let us place a percolator lifter in the still. Instead of a perforated pan at the top of the liquid lifter as in a coffee pot, which lets the water flow right back, we will catch the water at a level above the absorber so that it can flow into the absorber by gravity. The alcohol vapor takes the place of steam in the coffee pot. We simply let the vapor pass on to the "worm" or condenser.

We actually do not need water cooling. We can simply put cooling fins on the condenser pipe and let the atmosphere cool it, as the air cools the radiator in our automobile. Due to the "air cooling" the alcohol vapor is liquefied.

The absorber will become warm as the alcohol dissolves, so we must cool the absorber as well as the condenser.



We utilize the principle of the coffee percolator lift to raise water with the alcohol vapor so that the water can flow through the absorber without the use of moving parts.

This part we can also "air cool." This "air-cooling" can also be accomplished by the simple device of placing fins on the absorber pipe and letting a natural flow of air take place over the outside of the absorber.

Since both the condenser and absorber are "air-cooled" they can be arranged so that the same flow of air cools both, first flowing in contact with the absorber and then in contact with the condenser. This provides "natural draft" cooling without a fan or other moving parts.

In order to confine the hydrogen to its circuit, we can simply bend the pipes carrying liquid to this circuit so as to form traps.

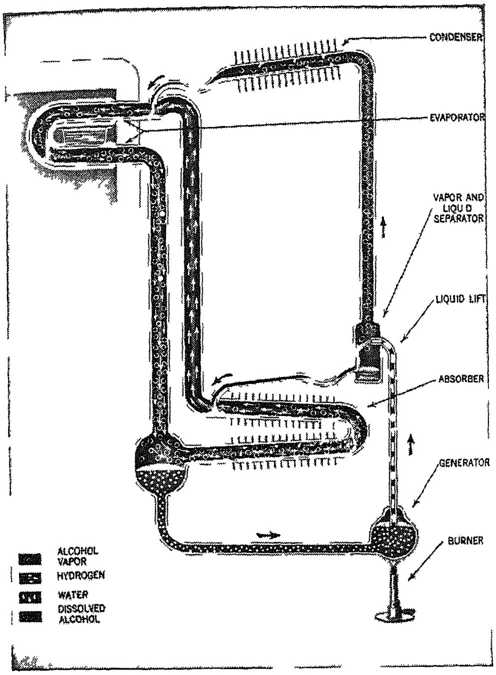
When we first produced cold by blowing into our evaporator, we used alcohol as the evaporating fluid. Alcohol could be used in the system, but ammonia is better. It requires less ammonia than alcohol to take up and transmit a certain amount of heat. Since we need to circulate less ammonia than alcohol to obtain the same amount of refrigeration, we are able to build a smaller unit if we use ammonia. Of course, compactness is very important in a household refrigerator.

The system will work the same way when using ammonia, but it requires a higher pressure to condense ammonia. This is accomplished by introducing the fluids into the unit under a suitable pressure before the unit is finally sealed in the factory.

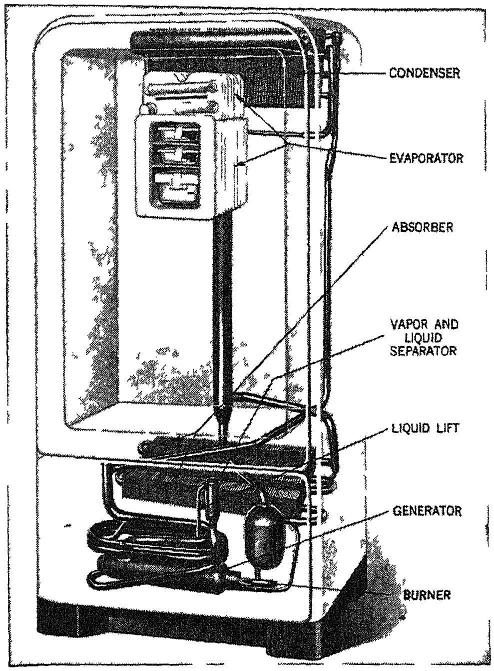
Controlling our refrigerator

We have built a refrigerator in which we apply heat to one part and at the same time produce refrigeration at a remote part. How can we control the amount of refrigeration produced so that the refrigerator box will be neither too warm nor too cold? If we analyze the system we have built up we will find that this problem solves itself.

Suppose we increase the supply of heat. This will drive off more vapor in the generator and consequently more will condense in the condenser. This means that more liquid will flow into the evaporator to evaporate and more intense cold will be produced. Also, since evaporation is increased, the circulation between the evaporator and the absorber will be intensified, because one vertical branch of the hydrogen circuit gets heavier as the evaporation is intensified. We have seen that by increasing the alcohol quantity and "blowing" more on it we can produce more cold. So, by merely varying the heat supply, the whole system can be made to give more or less refrigeration.



COLD FROM HEAT, IN PRINCIPLE



PRINCIPLE APPLIED TO PRACTICE

Since, in most cases, we are using a gaseous fuel, the regulation is easily accomplished by a simple thermostat. The thermostat bulb is placed in the box near the evaporator and it "feels" the temperature. When it is too warm it causes expansion of a simple diaphragm to give a wider opening of a valve in the gas supply line. When it is too cold, it reduces the gas supply to the burner.

Also we can easily control the burner flame for safety. A shut-off valve in the gas line is connected to a simple foolproof disk which has a finger extending into the burner flame. If the burner flame should go out, the finger quickly cools and so does the disk, and when it cools, it closes the shut-off valve. We can place a knob at any convenient place and have it connected to adjust the thermostat to a higher or lower temperature. This is easily done by an adjusting screw on the thermostat connected to be operated by the knob.

We have used gas as a convenient source of heat. It is most commonly used. In principle, however, we are not limited as to sources of heat. Another source of heat actually used for heating the actual refrigerator of this kind on the market is kerosene. The only difference is in the source of heat and its control. The reader will readily understand in principle how a kerosene burner can be substituted for the gas burner. The kerosene burner is also equipped with safety devices, though of different form. Even electricity is an available source of heat.

The hydrogen reserve vessel

Our system is "air cooled." It is air cooled by atmospheric air. The temperature of the atmosphere is high in summer and low in winter. Consequently we have a higher condenser temperature in the summer than in the winter.

In a condenser containing only ammonia, there is a relation between pressure and temperature. As the outside temperature varies, so the temperature inside the condenser varies and the pressure goes up and down with the tem-

perature. There is a relation between pressure and temperature in a fluid changing from liquid to vapor (and vice versa). A familiar illustration of this is the decrease in temperature at which water boils as we go up a mountain because of the decrease of atmospheric pressure. If the pressure in the condenser is too low in relation to the temperature, the ammonia will not condense.

In our system as we have built it up so far, the pressure must be high enough so that we will have condensation of ammonia in the ammonia condenser at the highest air temperature of the summer time. We can easily charge the system to accomplish this by adding enough hydrogen. But in that case we would be operating at a higher pressure during most of the year when we could very well do with much less pressure. We would prefer to have a lower pressure as much of the time as possible because it is easier to drive the ammonia out of solution at lower pressure, and this in turn results in lower operating cost.

Can we build the system so that we ordinarily have a low pressure and only increase the pressure on the hottest days? We can do this if we can have a reserve of hydrogen which is pushed into the evaporator-absorber circuit only when the air temperature is abnormally high.

So we make a reserve vessel for hydrogen and connect it to the system. Normally the hydrogen stays in this reserve vessel and we can operate normally at lower pressure. If the air temperature rises so high that the pressure is inadequate for condensation in the ammonia condenser, we simply push more hydrogen into the active part of the system from our reserve vessel. To push this hydrogen into the circuit we could use a pump or a piston. But we would like to accomplish this also without moving parts and automatically. Fortunately we have factors in our system which can be applied to accomplish this. We can push the hydrogen into the active part of the system by the ammonia which does not condense.

Therefore in place of using a pump or piston, we simply connect our reserve vessel to the outlet of the ammonia condenser. If the ammonia vapor cannot condense, it must pass through our new pipe to the reserve vessel. This displaces the hydrogen out into the active part of the system. The ammonia vapor now in the reserve vessel corresponds to a quantity of ammonia (by weight) which was previously in solution and therefore occupied only a fraction of the space it now occupies in the reserve vessel. The hydrogen is still a gas. Due to the greater proportion of gaseous to liquid ammonia in the system, the pressure is higher, which permits adequate condensation in the ammonia condenser.

When the outside temperature becomes normal again, the condenser action is intensified and the ammonia is drawn back into the active part of the system from the reserve vessel; and the hydrogen is drawn back into the reserve vessel.

The Twentieth Century (1895-) IX

by JUSTUS SCHIFFERES

THE ROAD AHEAD IN SCIENTIFIC RESEARCH

THE scientists of one generation can never tell what developments the next generation will bring about. Certainly the physicists of the 1890's never dreamed that the apparently immutable law of gravitation laid down by Newton would be successfully challenged by Einstein. The chemists of the 1890's would have been appalled to learn that their neatly ordered system of indivisible atoms was a delusion; that the atom, far from being indivisible, is a miniature world consisting of many parts. The biologists of the same period did not have the slightest inkling that the study of genetics would be revolutionized by the discovery of genes — the tiny bearers of hereditary traits.

It is clear that any attempt to point out the road ahead in science must be largely guesswork. Yet, with the reader's permission, we are going to risk some guesses — "predictions" is the more dignified word — about what science has in store for mankind. These guesses are based, as far as possible, on past achievements and present trends.

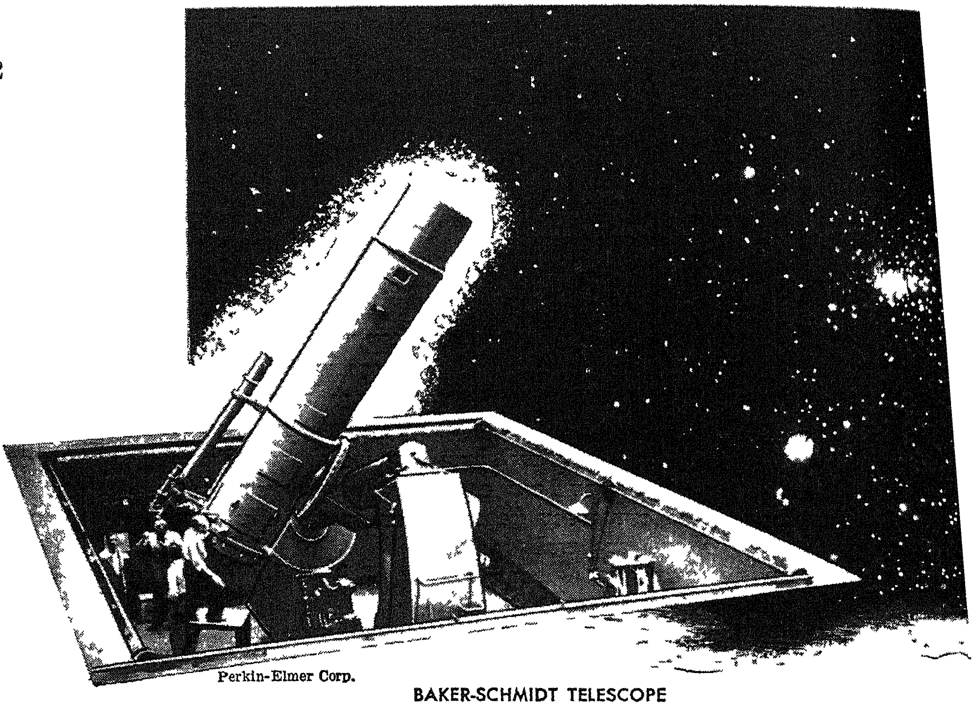
It seems altogether likely that in the future, as at present, important contributions will be made by organized scientific groups. Teams of scientists, trained in different disciplines, will pool their knowledge in order to attack major problems. They will be backed by the mighty resources of government agencies, private institutions and voluntary societies. Industrial research laboratories will study many of the basic problems of science. In all these joint undertakings, great numbers of obscure individuals will toil selflessly, each contributing his bit.

It is likely, however, that future scientific progress will not depend entirely, or even perhaps chiefly, upon such organized efforts. To quote Irving Langmuir, a Nobel Prize winner in chemistry: "Only a small part of scientific progress has resulted from a planned search for specific objectives. A much more important part has been made possible by the freedom of the scientist to follow his own curiosity . . . It is not reasonable to expect that directors of laboratories or boards set up to direct scientific work are supermen who can foresee new knowledge before it exists."

The future of science will rest, to a considerable extent, with the individual scientist of genius, endowed with great ability, insatiable curiosity and infinite perseverance. "Genius flashes forth like a meteor, unproduced and unpredictable," wrote the American astronomer Forest Ray Moulton. "It is not limited to any race of people, or to any particular latitude or longitude. It has often come up from obscurity and has flourished under poverty and persecution as well as under the smiles of Fortune . . . At present we can only hope that it will come often."

Fortunately, genius has a way of asserting itself in every age. We may feel confident that there will be future Aristotles, Galileos, Newtons, Faradays, Pasteurs, Freuds and Einsteins to provide new insight into the eternal mystery of the universe.

There is every reason to believe, too, that earnest amateurs will make contributions to the future development of science. Businessmen and factory workers and housewives will scan the heavens in


Perkin-Elmer Corp.

BAKER-SCHMIDT TELESCOPE

search of hitherto unknown comets; they will call the attention of biologists to new species of animals and plants; they will take part in statistical surveys. In other ways, too, they will make valuable forays into the realms of the unknown.

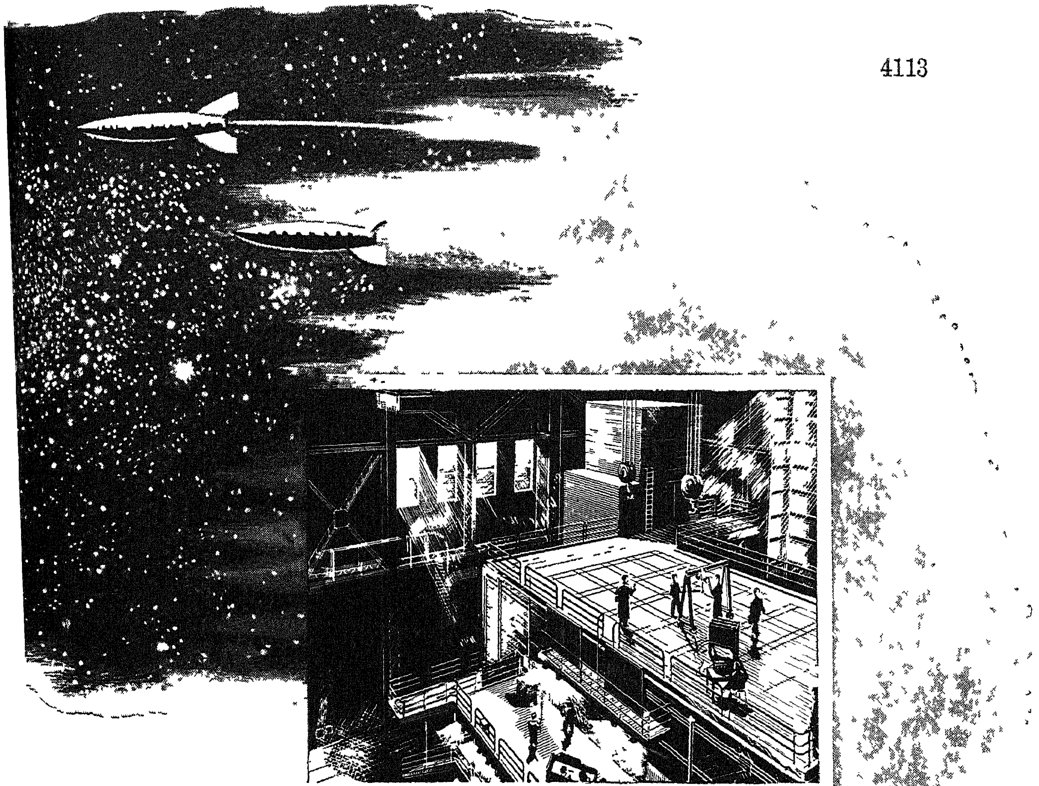
Into what new paths will these devoted professional and amateur scientists penetrate? It seems probable that the electron microscope will open new worlds within worlds, especially in the sciences of genetics and virology (the study of viruses and virus diseases). With the 200-inch Palomar Mountain telescope and other giant telescopes yet to be built, more and more of the heavens will be revealed to mankind. Rockets soaring hundreds of miles above the surface of the earth will help solve the mysteries of upper space.

The science of nucleonics, dealing with the phenomena of the atomic nucleus, will offer a fertile field. Through tagged atoms — radioactive isotopes — men will learn much about the mysterious borderland between the living and the dead, the organic and the inorganic worlds. Atomic energy will be harnessed more fully. The physical properties of matter under the bombardment of atomic bullets will be more fully analyzed. Today the nucleus of the atom is almost unknown territory. It will be explored, mapped and exploited.

We have still much to learn about the process of aging — the subject matter of the new science of gerontology. Reputable scientists maintain that the average span of life of the human race can be increased to 150 years. They hold, too, that the diseases that now beset the aged will be conquered. Some day, they say, men will wonder at Shakespeare's famous description of old age (in As You Like It, Act II, Scene 7) as

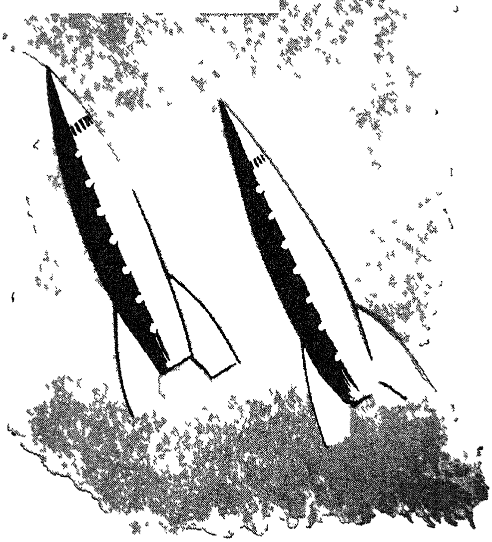
> ". . . second childishness and mere oblivion,
> Sans [without] teeth, sans eyes, sans taste,
> sans everything."

The ideal antiseptic, the ideal anesthetic still remain to be found. We have much to learn about photosynthesis. Some future investigator, perhaps, will find a way to carry on artificial photosynthesis — that is, to manufacture food in sunlight, as plants do. Psychologists will look into the possibilities of mental telepathy. Emotional illnesses will be better understood and more readily cured. Mineral treasures will be extracted from the oceans. Progress in the seeding of clouds will bring abundant rainfall to crops.



Brookhaven National Laboratory

BROOKHAVEN NATIONAL LABORATORY NUCLEAR REACTOR



FUTURE SPACE FLIGHT

Scientists are already working on the problem of travel in space; informed opinion holds that the first trip to the moon will take place in the present century. In time such flights may possibly become a commonplace. Some day, indeed, man's crust of earth may be so densely populated that interplanetary migration may be a grim necessity. Do not scoff; remember that many of the fantasies of yesterday have become the realities of today. Unquestionably there are limits to human achievement; but who knows what they are?

In the chapters of this group, we have given an outline of science as we can write it today. By following the map of the history of science, you can reach its outposts; beyond that, you are on your own. Some of you who read these lines may pass beyond the "endless frontier" of present scientific knowledge and may help to write the history of science of the future.

"Science is adventure — man's great adventure with the universe," said an eminent American scientist, Edmund Ware Sinnott. If the inspiring annals of science are any criterion, there will never be a dearth of scientific adventurers ready to meet the challenge of the unknown.

This is the last chapter of SCIENCE THROUGH THE AGES.

SOURCE OF MATERIALS USED IN "KZ PERFUME"

ODORS		NATURAL OR SYNTHETIC		SOURCE
Floral Odors	Jasmine	Synthetic	Basic odor due to benzyl acetate made from	Coal Tar
	Violet	Synthetic	Mixture of the ionones made from	Oil of Lemongrass
	Rose	Synthetic	A blend made up of a mixture of synthetics:	
			1. Phenylethyl alcohol made from	Coal Tar
			2. Geraniol, geranyl acetate, citronellol made from	Oil of Citronella
			3. Rhodinol obtained from	Oil of Geranium
	Lily of the Valley	Synthetic	Basic odor due to hydroxycitronellal made from	Oil of Citronella
	Carnation	Synthetic	Basic odor due to iso-eugenol made from	Oil of Cloves
	Orange Blossom	Natural	Natural oil obtained by extraction with volatile solvents from	Blossoms
	Mimosa	Natural	Natural oil obtained by extraction with volatile solvents from	Flowers
Oriental Odors	Sandalwood	Natural	Natural oil obtained by steam distillation from	Wood
	Vetiver	Natural	Natural oil obtained by steam distillation from	Roots
	Styrax	Natural	Natural resin	Resin
	Patchouli	Natural	Natural oil obtained by steam distillation from	Grass
Odors added to modify the odor of the perfume	Coumarin	Synthetic	Substance having the odor of new mown hay made from	Coal Tar
	Oak Moss	Natural	Natural resin having an earthy odor extracted from	Moss
	Ylang Ylang	Natural	Natural oil obtained by steam distillation from	Flowers
Fixative and Diluting Agent	Musk Ambrette	Synthetic	Made from	Coal Tar
	Alcohol	Synthetic	Made by fermentation from	Molasses or Grain.

Illustrations and information given in this section are based on a lecture and demonstration given by Dr. N. H. Smith of the Chemistry Section of the Franklin Institute, Philadelphia, Pa.

SYNTHETIC PERFUMES

By

THEODORE KILLHEFFER

Technical Assistant, Fine Chemicals Division, E. I. du Pont de Nemours & Co.

ONE OF THE MOST FASCINATING chapters in the history of the synthetic chemical industry deals with the extraordinary changes which have occurred in the ancient art of perfume making because of the new materials made possible by modern science.

These synthetic perfume ingredients enable the perfumer to use equally good raw materials, in greater quantities, and of much improved uniformity and stability. In some cases the synthetics are better than the natural raw materials and provide the finished product in a greater range of availability at tremendously lower costs.

There has been no substantial improvement made in the extraction of natural oils. It takes nearly twenty-five tons of violets to make one ounce of the natural oil. Today the violet odor is produced synthetically. Up until recently a ton of roses was needed to obtain ten ounces of the natural oil. A chemical triumph was accomplished when this odor was reproduced in the laboratory.

Lilac could not be produced until it was made by synthesis, for no satisfactory means has ever been found of extracting the natural oil. Moreover, there is no known natural extract so sweet or so peculiarly powerful in odor as synthetic lilac. Similarly, there was no lily-of-the-valley perfume until it was produced synthetically.

Completely new qualities, not found in nature's materials, have been achieved by the chemist, who has evolved numerous shades of each odor type, and has created entirely new perfume bases. These developments have been such that, today, most perfumes on the market depend on synthetics for their individuality and character. And the whole gamut of aromatics now consists of perhaps a thousand materials against a former fifth of that number, with the list of synthetics being constantly increased due to the efforts of the organic chemist.

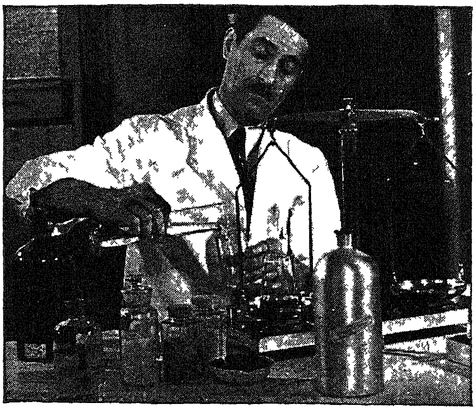
But perhaps the greatest triumph of all came with the development of a true synthetic musk, not to be confused with the nitro or artificial musks (known as Musk Ambrette, Musk Ketone, and Musk Xylol). The latter, which were also developed chemically, are only similar to natural musk in their general odor effect. Due to this similarity and their physical properties, they are also of use as fixatives. Their particular defect is due to the nitro groups which cause them to discolor many of the compounds in which they are placed.

Musk is the most important single material used in perfumery. It is a fixative, which means that it blends in one fragrance the many odors used in a perfume, and confers permanence on the more evanescent perfume odor, the musk acting to the odor almost as a mordant does to a dyestuff. A fixative is required in every perfume. Better than any other known substance, musk performs this function, blending and exalting all other perfume materials. It is highly powerful and sweet, and is said to be the most fascinating of all odors to human beings.

So great has been the demand for musk in modern perfumery that the male

musk deer of Tibet, from whose glands the natural musk grains are extracted, was being exterminated. The cost of natural musk, as found on the market with all its accompanying impurities, most of which have no odoriferous qualities, reached $560 a pound. If it could be had in a perfectly pure state, it would be worth $40,000 a pound. But natural musk cannot practically be appraised chemically. It thus lends itself to adulteration, which means that, apart from the financial loss, the best results in perfumery cannot surely be achieved.

Into this picture came the chemist,

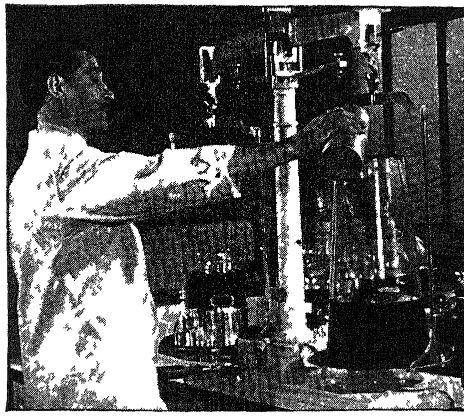


Here the perfume ingredients undergo a quantitative test to determine their purity and strength.

who developed a product as powerful as the intrinsic essence of natural musk, which can be chemically appraised and is thus of a determined strength and immediately usable. Such an organic chemical, known as "Astrotone" synthetic musk, is made and sold in commercial quantities by the du Pont Company.

With the discovery of each new synthetic, advances are made in the creation of new odor combinations, and some of these new groupings have become outstanding perfumes. Such combinations were not possible heretofore, because their ingredients were not available. In this respect, the new synthetics were directly responsible for their achievements. But over and above this fact, it was the artistry of the perfumer linked with the chemical advances of the laboratory which, in reality, were jointly responsible for these novel, and, very often, extremely popular new odor combinations.

It was, for example, the discovery of an aliphatic aldehyde, named lauric aldehyde, a synthetic which comes from coconut oil, that made possible one of the most famed French perfumes of all times. Lauric aldehyde has a powerful high note, so powerful that although it forms the base of a large range of the best perfumes of today, only a few pounds of this substance are used each year.



All photos courtesy Coty

Assembling a perfume formula requires accuracy. The odor is influenced by the order in which ingredients are combined

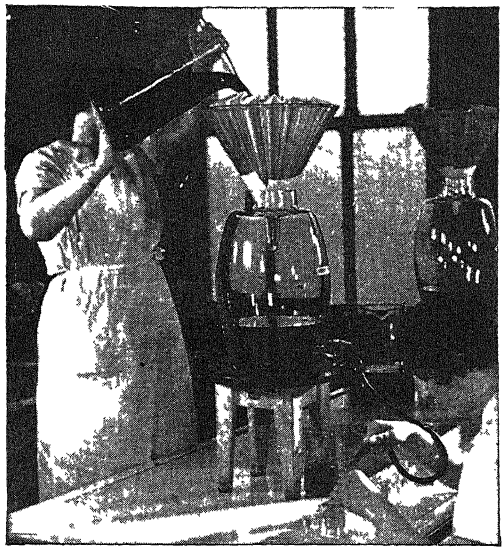
So important are the aliphatic aldehydes, mostly derived from coconut oil (each a synthetic and each representing a different perfume note) that they supply today the distinctive note of many well-known French perfumes of the modern type. Other aliphatic aldehydes suggest the odors of rose, tuberose, iris, violet and incense.

In résumé, the chemist has done far more than to reproduce nature's products. He has increased raw materials for perfumes several fold. He has discovered odors and fixatives with qualities which are not found in nature. He has reproduced perfume components which, apart from contributing a desired odor, are free from certain undesirable by-constituents found in natural oils and are uniform in quality, thus leaving the

perfumer more unrestricted in his blending, a factor which alone has made possible a whole new realm of perfume effects.

Perfume materials come from all over the world. The principal flower oils are obtained from southern France, but most European countries supply many important perfume components derived from flowers, roots, seeds, fruit, bark, and gums. Africa, Asia, and the East Indies furnish ingredients from grasses, roots, seeds, bark, and gums, including the herbs and spices of importance since

Aging for several months in copper casks helps to "cure" and blend the perfume



Filtered through three filter papers, the perfume is bottled by hand as the best way of avoiding losses from dripping

Biblical times. The Western World only recently has been providing many products for the perfumer's use, much of the recent activity being spurred on by wartime shortages. The work of the chemist has partially relieved our dependence on foreign sources of supply.

Finally in this field, chemical research through the development of new materials, has made available to the perfumer products whose use heretofore was prohibitive because of the excessive cost of the natural materials.

The making of perfumes

On page 4114 are shown the components of one of the most popular and expensive French perfumes now on the market. For simplicity, and since the manufacturer is not at liberty to give its real name, this perfume is referred to as KZ. The making of this perfume is representative of the making of fine perfumes today.

Perfume making is both an art and a science, for the materials are supplied by the chemist—whether he extracts them from natural sources or creates synthetic components—but the blending calls for the perfumer who works, like an artist, by inspiration. It takes a great artist to create a rare perfume, for not enough is yet known of the perfumer's work to proceed by scientific formula.

Three types of ingredients enter into perfumes: (1) Odoriferous components, usually many in number, supply the main substance of the perfume odor. If of natural origin, they come from such sources as the oils of flowers, roots of plants, trees, barks, gums and resins, seeds, leaves, stems, grasses, and fruits. (2) The diluting agent is a pure and odorless alcohol produced by the fermentation of molasses or grain, and purified by special chemical processes. (3)

The fixative blends the many odors into one and confers permanence on the perfume odor. Musk, civet, castoreum from beavers, and ambergris from whales are the most important of the natural fixatives. Until recently the fixatives were exclusively of animal origin. Now, however, synthetic fixatives are used very extensively. In KZ, artificial musk is chosen for this purpose.

It may seem strange that so large a number of odors is used to produce a single perfume. But to make this odor as it should be is a highly complicated matter. In the first place, a sweet odor alone is not pleasing. Some artists paint in one color only, but, by a judicious use of shades and tints, can produce most pleasing results. Artists in perfumery do the same. And just as oil paintings have a warmth, depth, feeling, and significance, due to imaginative use of colors, even colors which, taken individually, are not pleasing, so perfumes have added life, warmth, depth, and appeal, due to the careful blending of many different odoriferous ingredients by perfume artists. Several basic groupings have been proposed by perfume authorities. One such grouping includes four odor types. These are sweet, acid, burnt, and goat odor. This variety explains some of the seemingly strange sources for perfume materials. It is from a combination of basic odors that a pleasing odor is obtained. Some of the most valued substances for perfumes, such as civet, are extremely evil-smelling. These materials have had special importance of late because many of the most popular perfumes contain a large percentage of the unpleasant odors.

In addition to being pleasing, the principal odor must also be subtle. If strong, it quickly paralyzes the sense of smell, just as a loud noise deafens one or a bright flash of light causes momentary blindness. A subtle odor, however, can be noticed for a long time.

The perfumer is also constantly seeking new odors. He must, therefore, assemble many odors to arrive at these various requisites. He may choose all florals for a very sweet perfume; or all woody odors for an Oriental perfume which is heavy; but the general preference is for a combination of these two—as used in KZ—producing a bouquet type.

Whatever the perfume type, the main substance of the odor in a fine product consists of natural oils which supply the basic note, but the character and individuality are developed through the careful compounding of natural and synthetic products.

The extraction of natural oils as well as the production of synthetic odors, requires the chemist's skill, for a process suitable for one natural oil may decompose another. The methods used are the steam distillation process, extraction with a volatile solvent such as acetone or benzene, the squeezing process, and enfleurage.

Just as butter absorbs a fish or onion odor, so a fat such as lard absorbs the odor from a flower or plant. Glass trays are coated with fat and then covered with fresh flowers, and the fat is allowed to stand so that the odorous constituent from the flower is absorbed.

This process, known as enfleurage, is the method used in the first perfume making in Egypt and is still extensively used in France for recovering the perfume from jasmine and tuberose. The lard or fat is then washed with alcohol or benzene to separate the perfume.

To extract the natural oils from orange blossoms and mimosa in KZ, the method of extraction with a volatile solvent (such as benzene) is used. In this case, by a series of processes the natural oil is transferred from the flower to the benzene; in the last step the benzene is evaporated, leaving the perfume oil free.

Steam distillation is used for such odors as sandalwood which comes from a tree; vetiver, a natural oil which comes from roots; or patchouli which comes from grass. The sandalwood or other natural product is boiled in water. Then steam is blown through the mixture, carrying the vaporized oil to a condenser where the water and oil are condensed

as liquids. Because the oil does not mix with water, and because it is lighter than water, the oil which carries the perfume comes to the top and is removed.

Oils of the citrus fruits—orange, lemon, bergamot, etc.—are secured by hand. The rinds of these fruits are cut into strips and removed from the fruit, being placed in water to soak for a short time. They are then squeezed against small sponges which take up the oil. These are afterward pressed or dissolved out, according to the process used. As the quality of these oils is adversely affected by heat, they are distilled at a low temperature in a vacuum.

The odors which come from roots, barks, etc., must be aged for months in alcohol before the full odor is brought out, making these materials suitable for use in perfumes. This is because such substances have but a slight apparent odor. Orris root is a striking example and the perfume from it, when aged, is extremely powerful and odoriferous. This necessary aging of certain natural odors has been another factor giving impetus to the production of synthetics, which do not have this drawback.

The production of synthetic odors

Some of the most important synthetic components for KZ and many other perfumes are made by the chemist from coal tar. Usually in making these odors, the chemist is required to make other substances as an intermediate step. For example, the chemist analyzes the rose odor and finds that it is composed of many chemical substances, one of which is phenyl ethyl alcohol, the main component of rose water. Therefore, in order to produce rose water synthetically, he may work as follows:

When coal tar reaches 230° F., toluene, a water-like material which smells like gas is recovered. The chemist treats this toluene with chlorine and gets benzyl chloride, which he treats with potassium cyanide. This, as a result of further chemical operation, produces phenyl ethyl alcohol, a sweet-smelling substance, which is the main component of rose water when manufactured synthetically.

Or, the chemist may treat the benzyl chloride with sodium acetate and obtain benzyl acetate, whose odor note is one of the main odor notes of jasmine. In fact, chemical analysis has shown that natural jasmine contains 65 percent of the pure chemical, benzyl acetate, built up by nature.

In making the fixative for this particular perfume, too, the chemist must deal with what would seem to be remote materials. When coal tar reaches 392° F., the chemist obtains cresol, which, when subjected to suitable chemical treatment yields Musk Ambrette, the fixative for KZ.

Among the other odors produced synthetically and used in KZ is carnation, of which oil of cloves is the base. From this natural oil, a chemical, eugenol, is extracted and treated, arriving at iso-eugenol, which has the desired delicate odor. Iso-eugenol, if further treated, becomes vanillin, used in combination with natural vanilla for most vanillas on the market.

By other chemical processes the two main components of oil of rose, geraniol and citronellol, are derived from natural oil of citronella. Also from oil of citronella come essential parts of synthetic lily-of-the-valley and lilac perfume, neither of which could be made until the chemist produced these odors synthetically.

After the component parts have been blended, the perfume is aged to develop fully its rich and mellow qualities.

Synthetic perfumes in soaps and cosmetics

The development of synthetic components for perfumes has been of major importance in the soap and cosmetic industries, where perfumes are used in some cases to cover up the bad odor of fats, in others to give a pleasing smell. Every cosmetic and soap on the market is perfumed—even the cheapest type of laundry soap.

First and foremost of the long-stand-

ing problems of soap perfumery has been the cost element. The use of a great number of natural perfume oils would make the cost of our modern soaps prohibitive. Until synthetic perfumes were developed, only such odors as lemon, lavender, and bergamot, and a few Oriental perfumes, such as sandalwood and honey, were used in soaps, and these were highly expensive. Now, however, the use of synthetic aromatics permits the reproduction, in soap, of even the most expensive of the favorite new bouquet odors, and at a very real saving in cost over using the natural oils.

Secondly, in the making of soaps, the evaporation of perfumes is an important factor, and great care should be taken to select aromatics with high boiling points, especially for soaps where the perfume is added to the soap mass while it is still molten. In the case of certain odors, where the natural essential perfume oils would disappear on account of their low boiling point, the use of certain high boiling point synthetics helps to retain the desired perfume odor in the soap. Uniformity of quality in perfume is also of the utmost importance in producing a satisfactory soap or cosmetic. Here again, synthetics are superior, for natural oils vary within themselves, whereas synthetic components are, in general, more uniform.

Still another problem is that the perfume must not discolor cosmetics—a requisite to some extent, too, for soaps, as there is considerable preference in the U. S. for white soaps. The majority of synthetic odors are colorless and many are non-discoloring.

In cosmetics, there is another special problem that the perfume must not be positive or definite, since the cosmetic manufacturer cannot afford to restrict his product to the few to whom a positive perfume might appeal. This difficulty has been overcome with the vast increase in raw materials due to synthetic developments.

Finally, because of the enormous volume which these industries represent and the fact that soaps and even certain cosmetics are classified as necessities rather than as luxuries, the question of adequate domestic supply as well as price is of great magnitude.

Already the chemist has gone far toward overcoming these various obstacles and each year natural perfume oils in soaps and cosmetics are being more and more replaced with synthetic components. Here again, it is not price and supply alone, but even more, the development of products superior to anything made by nature, that accounts for this vast advance in synthetics.

Perfume usage in industrial products and processes

The significance of synthetic developments in perfumes goes far beyond perfumes proper, soaps, cosmetics, toilet goods, etc., for perfumes enter into a vast range of industrial products and processes. They may be used, for example, in fabrics to cover up the bad odor of certain products used in finishing. Similarly, they enter into paints, leather, linoleum, medicines, ink, whisky, foods, and a multitude of other products. Many objects of daily use would be unusable because of bad odor, were it not for perfumery.

A recently developed perfume usage of interest is in connection with air conditioning. Air conditioning brings a cooler temperature but an atmosphere lacking in the freshness of the out-of-doors. By the use of certain perfumes, it is now possible to supply this freshness.

The products and processes requiring perfumery are constantly widening as scientific research progresses. It would not be possible to develop these products and processes for widespread use were it not for synthetics in perfumes which are solving the problems of supply, uniformity, cost, and needed new qualities.

APPENDIX AND ALPHABETICAL INDEX

APPENDIX

LIST OF CHEMICAL ELEMENTS

Elements	*Symbol*	*Atomic No*	*Atomic Weight*	*Elements*	*Symbol*	*Atomic No*	*Atomic Weight*
Actinium	Ac	89	227	Neon	Ne	10	20.183
Aluminum	Al	13	26 97	Neptunium	Np	93	239
Americium	Am	95	241	Nickel	Ni	28	58.69
Antimony	Sb	51	121.76	Niobium	Nb	41	92.91
Argon	A	18	39.94	Nitrogen	N	7	14.008
Arsenic	As	33	74.91	Osmium	Os	76	190.2
Astatine	At	85	211	Oxygen	O	8	16.0000
Barium	Ba	56	137.36	Palladium	Pd	46	106.7
Berkelium	Bk	97	243	Phosphorus	P	15	30.98
Beryllium	Be	4	9.02	Platinum	Pt	78	195 23
Bismuth	Bi	83	209.00	Plutonium	Pu	94	239
Boron	B	5	10.82	Polonium	Po	84	210
Bromine	Br	35	79.916	Potassium	K	19	39.096
Cadmium	Cd	48	112 41	Praseodymium	Pr	59	140.92
Calcium	Ca	20	40 08	Promethium	Pm	61	147
Californium	Cf	98	244	Protactinium	Pa	91	231
Carbon	C	6	12.010	Radium	Ra	88	226.05
Cerium	Ce	58	140.13	Radon	Rn	86	222
Cesium	Cs	55	132.91	Rhenium	Re	75	186.31
Chlorine	Cl	17	35.457	Rhodium	Rh	45	102.91
Chromium	Cr	24	52.01	Rubidium	Rb	37	85.48
Cobalt	Co	27	58.94	Ruthenium	Ru	44	101.7
Copper	Cu	29	63.54	Samarium	Sm	62	150.43
Curium	Cm	96	242	Scandium	Sc	21	45.10
Dysprosium	Dy	66	162.46	Selenium	Se	34	78 96
Erbium	Er	68	167.2	Silicon	Si	14	28.06
Europium	Eu	63	152.0	Silver	Ag	47	107 880
Fluorine	F	9	19.00	Sodium	Na	11	22 997
Francium	Fa	87	223	Strontium	Sr	38	87 63
Gadolinium	Gd	64	156.9	Sulfur	S	16	32.066
Gallium	Ga	31	69 72	Tantalum	Ta	73	180 88
Germanium	Ge	32	72.60	Technetium	Tc	43	99
Gold	Au	79	197.2	Tellurium	Te	52	127.61
Hafnium	Hf	72	178.6	Terbium	Tb	65	159.2
Helium	He	2	4 003	Thallium	Tl	81	204.39
Holmium	Ho	67	164.94	Thorium	Th	90	232.12
Hydrogen	H	1	1.0080	Thulium	Tm	69	169.4
Indium	In	49	114.76	Tin	Sn	50	118.70
Iodine	I	53	126.92	Titanium	Ti	22	47.90
Iridium	Ir	77	193.1	Tungsten,			
Iron	Fe	26	55 85	see Wolfram			
Krypton	Kr	36	83.7	Uranium	U	92	238 07
Lanthanum	La	57	138 92	Vanadium	V	23	50.95
Lead	Pb	82	207.21	Wolfram			
Lithium	Li	3	6.940	(Tungsten)	W	74	183.92
Lutetium	Lu	71	174.99	Xenon	Xe	54	131.3
Magnesium	Mg	12	24.32	Ytterbium	Yb	70	173.04
Manganese	Mn	25	54.93	Yttrium	Y	39	88.92
Mercury	Hg	80	200.61	Zinc	Zn	30	65.38
Molybdenum	Mo	42	95.95	Zirconium	Zr	40	91.22
Neodymium	Nd	60	144.27				

THE PERIODIC TABLE

In the year 1869 the Russian chemist Dmitri Ivanovitch Mendeleev showed that if the chemical elements were listed according to their atomic weights, they would fall into certain groups, following a recurring sequence. He showed, too, that the elements within each group exhibited strikingly similar chemical behavior. The idea had been suggested a few years before by an English chemist, J. A. R. Newlands, but Mendeleev was the first to work out a detailed system of periods, or sequences, for the elements. He was able to deduce the existence of certain unknown elements that were missing in his time in some of the sequences. For example he predicted, fifteen years before its discovery, the existence of the element now known as germanium.

The name of "periodic table" was given to the arrangement of the elements in the manner indicated above. In the modern version of the periodic table, the elements are listed according to their atomic numbers. With a few exceptions, the order is the same as it would be if the elements followed the order of their atomic weights.

In the following table, the figure in italics above the symbol standing for a given element is the atomic number. The figure to the right of the symbol represents the approximate atomic weight in terms of the nearest whole number. You will find elsewhere in this Appendix the list of symbols, together with the corresponding elements.

GROUP O	GROUP I		GROUP II		GROUP III		GROUP IV		GROUP V		GROUP VI		GROUP VII		GROUP VIII		
	1 H 1																
2 He 4	*3* Li 7		*4* Be 9		*5* B 11		*6* C 12		*7* N 14		*8* O 16		*9* F 19				
10 Ne 20	*11* Na 23		*12* Mg 24		*13* Al 27		*14* Si 28		*15* P 31		*16* S 32		*17* Cl 35				
	*Gr. Ia	Gr. Ib	Gr. IIa	Gr. IIb	Gr. IIIa	Gr. IIIb	Gr. IVa	Gr. IVb	Gr. Va	Gr. Vb	Gr. VIa	Gr. VIb	Gr. VIIa	Gr. VIIb			
18 A 40	*19* K 39	*29* Cu 64	*20* Ca 40	*30* Zn 65	*21* Sc 45	*31* Ga 70	*22* Ti 48	*32* Ge 73	*23* V 51	*33* As 75	*24* Cr 52	*34* Se 79	*25* Mn 55	*35* Br 80	*26* Fe 56	*27* Co 59	*28* Ni 59
36 Kr 84	*37* Rb 85	*47* Ag 108	*38* Sr 88	*48* Cd 112	*39* Y 89	*49* In 115	*40* Zr 91	*50* Sn 119	*41* Nb 93	*51* Sb 122	*42* Mo 96	*52* Te 128	*43* Tc 99	*53* I 127	*44* Ru 102	*45* Rh 103	*46* Pd 107
54 Xe 131	*55* Cs 133	*79* Au 197	*56* Ba 137	*80* Hg 201	*57* La 139 58-71 Rare earths **	*81* Tl 204	*72* Hf 179	*82* Pb 207	*73* Ta 181	*83* Bi 209	*74* W 184	*84* Po 210	*75* Re 186	*85* At 211	*76* Os 190	*77* Ir 193	*78* Pt 195
86 Rn 222	*87* Fa 223	*97* Bk 243	*88* Ra 226	*98* Cf 244	*89* Ac 227		*90* Th 232		*91* Pa 231		*92* U 238		*93* Np 239		*94* Pu 239	*95* Am 241	*96* Cm 242

* Gr. indicates group.
** Rare earths· *58*, Ce 140; *59*, Pr 141; *60*, Nd 144; *61*, Pm 147; *62*, Sm 150; *63*, Eu 152; *64*, Gd 157; *65*, Tb 159; *66*, Dy 162; *67*, Ho 165; *68*, Er 167; *69*, Tm 169; *70*, Yb 173; *71*, Lu 175.

Atmosphere (conventional unit of pressure per unit of area): 14.697 pounds per square inch.

Acceleration due to gravity at sea level, 45° latitude: 980.665 centimeters per second per second or 32.172 feet per second per second.

Dyne: fundamental unit of force in centimeter-gram-second system of units; the force applied to a mass of one gram that gives it an acceleration of one centimeter per second per second.

Megadyne: 1,000,000 dynes.

Erg: fundamental unit of work in centimeter-gram-second system of units. One erg of work is done on a body when a force of one dyne is exerted upon it through a distance of one centimeter.

Joule: unit of work equal to 10,000,000 ergs.

Foot-pound: unit of work, equal to work done in raising one pound avoirdupois against the force of gravity the height of one foot; equivalent to 1.3549 joules.

Horse-power: unit of power, equal to a rate of 33,000 foot-pounds of work per minute.

Small calorie: amount of heat required at a pressure of one atmosphere to raise the temperature of one gram of water one degree centigrade.

Large calorie: amount of heat required at a pressure of one atmosphere to raise the temperature of one kilogram of water one degree centigrade.

British thermal unit (B.T.U.): quantity of heat necessary to raise the temperature of one pound of water one degree Fahrenheit at its point of maximum density. Equal to 252,000 calories (small).

Mean density of earth: 5.522 grams per cubic centimeter.

Density of mercury at 0° C.: 13.59559 grams per cubic centimeter.

Density of water at 3.98° C.: 0.999973 grams per cubic centimeter.

Density of dry air at 0° C. and at a pressure of one atmosphere: .001293 grams per cubic centimeter.

Velocity of light: 186,280 miles per second.

Velocity of sound in dry air at 0° C.: 1,087 feet, or 33,136 centimeters, per second.

TABLES OF WEIGHTS AND MEASURES

Linear Measure

12 inches	=	1 foot
3 feet	=	1 yard
5½ yards	=	1 rod
40 rods	=	1 furlong
8 furlongs	=	1 mile
5,280 feet	=	1 mile
3 miles	=	1 league

Square Measure (Area)

144 square inches	=	1 square foot
9 square feet	=	1 square yard
30¼ square yards	=	1 square rod
160 square rods	=	1 acre
43,560 square feet	=	1 acre
640 acres	=	1 square mile

Cubic Measure (Volume)

1,728 cubic inches	=	1 cubic foot
27 cubic feet	=	1 cubic yard
(measure for cordwood)		
16 cubic feet	=	1 cord foot (4'x4'x1')
8 cord feet or 128 cubic feet	=	1 cord (4'x4'x8')

Dry Measure

2 pints	=	1 quart	=	67.20 cubic inches
8 quarts	=	1 peck	=	537.61 cubic inches
4 pecks	=	1 bushel	=	2,150.42 cubic inches

Liquid Measure

4 gills	=	1 pint	=	28.885 cubic inches
2 pints	=	1 quart	=	57.75 cubic inches
4 quarts	=	1 gallon	=	231.0 cubic inches

Avoirdupois Weight

16 drams	=	1 ounce
16 ounces	=	1 pound
100 pounds	=	1 quintal
2,000 pounds	=	1 short ton
2,240 pounds	=	1 long ton

Apothecaries' Weight

20 grains	=	1 scruple
3 scruples	=	1 dram
8 drams	=	1 ounce
12 ounces	=	1 pound

Troy Weight

3.086 grams	=	1 carat
24 grains	=	1 pennyweight
20 pennyweights	=	1 ounce
12 ounces	=	1 pound

Time Measure

60 seconds	=	1 minute
60 minutes	=	1 hour
24 hours	=	1 day
7 days	=	1 week
365 days or 12 months	=	1 year
366 days	=	1 leap year
100 years	=	1 century

Circular Measure

60 seconds	=	1 minute
60 minutes	=	1 degree
60 degrees	=	1 sextant
90 degrees	=	1 quadrant
360 degrees	=	1 circumference

Nautical Measure

6 feet	=	1 fathom
1 cable's length	=	100 fathoms, ordinary; 608 feet, Brit.; 720 feet, U. S. Navy
1 nautical mile	=	6,080 feet, Brit.; 6,080.20 feet, U. S. Navy
1 knot	=	unit of speed, equal to 1 nautical mile per hour

Agate	= a size of type used in printing (5½ points)
Carat	= Unit of weight for precious stones, equal to 3.086 grains. Also means twenty-fourth part when used to indicate the proportion of gold in a gold alloy. Thus 10 carats fine means 10 parts gold and 14 parts alloy.
Gross	= 12 dozen
Hand	= 4 inches (used in measuring the height of a horse)
Pica	= a size of type used in printing (1/6 of an inch)
Point	= a unit of measurement used in printing (1/72 of an inch or 1/12 of a pica)
Quire of paper	= 24 or 25 sheets
Ream of paper	= usually 20 quires

THE METRIC SYSTEM

The metric system was established in France in 1793, has been adopted in many countries and is used to some extent in the United States and Great Britain. It is a decimal system based on the meter as a fundamental unit. Originally, the measurement of one ten-millionth of the earth's quadrant was taken as the length of the meter. For more accurate computation, the meter is now determined by the International Prototype Meter, a platinum-iridium bar, which is kept at the International Bureau of Weights and Measures in Sèvres, France, near Paris.

Linear Measure

10 millimeters	=	1 centimeter
10 centimeters	=	1 decimeter
10 decimeters	=	1 meter
10 meters	=	1 decameter
10 decameters	=	1 hectometer
10 hectometers	=	1 kilometer
10 kilometers	=	1 myriameter

Square Measure (Area)

100 square millimeters	=	1 square centimeter
100 square centimeters	=	1 square decimeter
100 square decimeters	=	1 square meter
100 square meters	=	1 square decameter (are)
100 square decameters	=	1 square hectometer
100 square hectometers	=	1 square kilometer
10,000 square meters	=	1 hectare

Cubic Measure (Volume)

1,000 cubic millimeters	=	1 cubic centimeter
1,000 cubic centimeters	=	1 cubic decimeter
1,000 cubic decimeters	=	1 cubic meter (stere)

Measure of Capacity

10 milliliters	=	1 centiliter
10 centiliters	=	1 deciliter
10 deciliters	=	1 liter
10 liters	=	1 decaliter
10 decaliters	=	1 hectoliter
10 hectoliters	=	1 kiloliter

Weights

10 milligrams	=	1 centigram
10 centigrams	=	1 decigram
10 decigrams	=	1 gram
10 grams	=	1 decagram
10 decagrams	=	1 hectogram
10 hectograms	=	1 kilogram or kilo
10 kilograms	=	1 myriagram
10 myriagrams	=	1 quintal
10 quintals or 1,000 kilos	=	1 metric ton

CONVERSION TABLE FOR WEIGHTS AND MEASURES

1 acre	= 0.4047 hectares
1 foot	= 0.3048 meters
1 foot, cubic	= 0.0283 cubic meters
1 foot, square	= 0.0929 square meters
1 inch	= 2.54 centimeters
1 inch	= 0.0254 meters
1 mile	= 1.6093 kilometers
1 ounce	= 28.3495 grams (avdp.)
1 pint, dry	= 0.5506 liters
1 pint, liquid	= 0.4732 liters
1 pound (avdp.)	= 0.4536 kilograms
1 rod	= 5.0292 meters
1 yard	= 0.9144 meters
1 yard, cubic	= 0.7646 cubic meters
1 yard, square	= 0.8361 square meters

1 centimeter	= 0.3937 inches
1 gram	= 0.0353 ounces (avdp.)
1 hectare	= 2.4710 acres
1 kilogram	= 2.2046 pounds (avdp.)
1 kilometer	= 0.6214 miles
1 liter	= 1.8162 dry pints
1 liter	= 2.1134 liquid pints
1 meter	= 3.2808 feet
1 meter	= 39.37 inches
1 meter	= 0.1988 rods
1 meter	= 1.0936 yards
1 meter, cubic	= 35.3144 cubic feet
1 meter, cubic	= 1.3079 cubic yards
1 meter, square	= 10.7639 square feet
1 meter, square	= 1.1960 square yards

THE BEAUFORT SCALE

Sir Francis Beaufort (1774-1857), a rear admiral in the English navy, devised a method in 1805 for gauging the apparent strength of the wind. The Beaufort scale was accepted by the British Admiralty and adaptations of it are still used by navigators and by the Weather Bureau in its forecasts. The Beaufort scale classifies the winds in thirteen groups, ranging from 0 to 12, as follows:

Scale Number	*Miles per hour*	*Description of wind*	*Indications on Land*
0	0 to 1	Calm	Smoke goes straight up
1	1 to 3	Light air	Smoke drifts
2	4 to 7	Slight breeze	Leaves rustle
3	8 to 12	Gentle breeze	Leaves and small twigs are in motion
4	13 to 18	Moderate breeze	Small branches move; dust and paper fly
5	19 to 24	Fresh breeze	Ripples on water; small trees sway
6	25 to 31	Strong breeze	Large branches move
7	32 to 38	High wind	The trunks of trees bend; walking is difficult
8	39 to 46	Gale	Twigs are broken off
9	47 to 54	Strong gale	Chimneys and shingles are carried away
10	55 to 63	Whole gale	Trees may be uprooted
11	64 to 75	Storm	Damage is widespread
12	Over 75	Hurricane	Any disaster may be expected

COMPARISON OF THERMOMETER SCALES

(F. = Fahrenheit; C. = Centigrade; R. = Réaumur)

	F.	C.	R.
(Boiling point: water)	212°	100°	80°
	194	90	72
	185	85	68
(Boiling point: alcohol)	167	75	60
	158	70	56
	140	60	48
	131	55	44
	122	50	40
	104	40	32
(Temperature of blood)	98	36.7	29.3
	86	30	24
	77	25	20
	68	20	16
	50	10	8
	41	5	4
(Freezing point: water)	32	0	0
	23	—5	—4
	14	—10	—8
	5	—15	—12
	0	—17.8	—14.2
	—13	—25	—20
	—22	—30	—24
	—31	—35	—28
	—40	—40	—32

(Centigrade $\times \frac{9}{5}$) + 32° = Fahrenheit
(Fahrenheit — 32°) $\times \frac{5}{9}$ = Centigrade
Réaumur $\times \frac{5}{4}$ = Centigrade
Centigrade $\times \frac{4}{5}$ = Réaumur
(Fahrenheit — 32°) $\times \frac{4}{9}$ = Réaumur
(Réaumur $\times \frac{9}{4}$) + 32° = Fahrenheit

ASTRONOMICAL CONSTANTS

Light-year: 5,880,000,000,000 miles.

Parsec: approximately 3.26 light-years or 19.2 trillion miles.

Velocity of light: 186,280 miles per second.

Astronomical unit (mean distance from sun to earth): 92,900,000 miles.

Mean distance from earth to moon: 238,854 miles.

Equatorial radius of the earth: 3,963.34 statute miles.

Polar radius of the earth: 3,949.99 statute miles.

Earth's mean radius: 3,958.89 statute miles.

Meridional circumference of earth: 24,860 miles.

Equatorial circumference of earth: 24,902 miles.

Sun's diameter: 864,000 miles.

Sidereal year (year measured with units that depend upon the apparent diurnal movement of the stars): 365.2564 days.

Tropical year (time elapsing between two passages in succession of the sun through the same equinox): 365.2422 days.

Sidereal month (month measured with units that depend upon the apparent diurnal movement of the stars): 27.3217 days.

Synodic month (time elapsing between two suc-

cessive passages of the moon between the earth and the sun) : 29.5306 days.

Sidereal day (day measured with units that depend upon the apparent diurnal movements of the stars) : 23 hours 56 minutes 4.091 seconds of mean solar time.

Mean solar day: 24 hours 3 minutes 56.555 seconds of sidereal time.

THE SUN, MOON AND PLANETS

Name	*Diameter in miles*	*Mass* (compared to that of earth)	*Density* (compared to that of earth)	*Mean distance from sun in miles*	*Period of revolution around sun*
Sun	864,000	329,290.	0.257		
Mercury	3,194	0.055	1.016	36,000,000	87.97 days
Venus	7,842	0.807	0.935	67,100,000	244.70 days
Earth	7,918	1.000	1.	92,900,000	365.26 days
Mars	4,263	0.107	0.716	141,700,000	686.98 days
Jupiter	89,229	314.5	0.243	483,400,000	11.86 years
Saturn	74,937	94.07	0.125	886,100,000	29.46 years
Uranus	33,181	14.40	0.246	1,782,700,000	84.02 years
Neptune	30,882	16.72	0.236	2,793,100,000	164.79 years
Pluto	4,000	0.1	?	3,666,100,000	248 years
Moon	2,160	0.012	0.609	Mean distance from earth: 238,854	Period of revolution around the earth: 29 days, 12 hours, 44.05 minutes

THE SIGNS OF THE ZODIAC

The celestial orbit described by the sun in its annual path among the stars is called the ecliptic. The zodiac is a theoretical division of the firmament, 16° in width, extending 8° on each side of the ecliptic. It begins at the point of the ecliptic that marks the position of the sun at the vernal equinox and proceeds toward the east. The zodiac is divided into twelve parts or signs of 30° each, they are named for the twelve constellations with which they corresponded at the time of Hipparchus (second century B.C.). The precession of the equinoxes in the two thousand years that have elapsed since that time has moved the signs 30° toward the west. The signs of the zodiac are:

♈ Aries (the Ram)

♉ Taurus (the Bull)

♊ Gemini (the Twins)

♋ Cancer (the Crab)

♌ Leo (the Lion)

♍ Virgo (the Virgin)

♎ Libra (the Balance)

♏ Scorpius (the Scorpion)

♐ Sagittarius (the Archer)

♑ Capricornus (the Goat)

♒ Aquarius (the Water-Bearer)

♓ Pisces (the Fishes)

APPARENT MAGNITUDE OF WELL-KNOWN STARS AND OTHER HEAVENLY BODIES

In the second century B.C., the Greek astronomer Hipparchus arranged the stars in six grades or classes, of brightness, or apparent magnitude. (As applied to a star, the word "magnitude" has to do with brightness and not with size.) The brightest stars were put in the first grade, the next brightest stars in the second grade and so on. Hipparchus' classification was adopted and improved by Ptolemy of Alexandria in the second century A.D. Our present system of apparent magnitudes is based on the work of these men, though the light values assigned to the different magnitudes have been greatly refined. In the case of the heavenly bodies that are brighter than the stars of the first magnitude, each increasing stage of brightness above 1 is indicated by the appropriate numeral (0, 1, 2, 3 and so on) preceded by a minus sign.

Sun	—26.7	Aldebaran	1.1
Moon	—12.5 at brightest	Antares	1.2
Venus	—4.3 at brightest	Spica	1.2
Mars	—2.8 at brightest	Pollux	1.2
Sirius	—1.6	Fomalhaut	1.3
Jupiter	—1.3	Deneb	1.3
Canopus	—0.9	Regulus	1.3
Alpha Centauri	0.06	Castor	1.6
Vega	0.1	Bellatrix	1.7
Capella	0.2	Mira Ceti	2.2 (variable)
Arcturus	0.2	Shedir	2.3
Rigel	0.3	Polaris	2.3
Procyon	0.5	Mizar	2.4
Betelgeuse	0.9 (variable)	Alcyone	3.
Altair	0.9	Alcor	4.
Saturn	1.	Uranus	6.
Mercury	1.		

NOBEL PRIZE WINNERS IN SCIENCE

Alfred Bernard Nobel (1833-96), the Swedish engineer who invented dynamite, left $9,000,000 in a fund to provide yearly awards for men and women whose work has benefited mankind. There are five Nobel Prizes—in physics, chemistry, medicine or physiology, literature and for the promotion of peace. The physics and chemistry prizes are awarded by the Royal Academy of Science in Stockholm; the medicine prizes by the Caroline Medical-Chirurgical Institute in Stockholm; the literature prizes by the Swedish Academy in Stockholm; the peace prizes by the Swedish Parliament. The names of candidates are submitted by persons qualified in the various fields. Although the winners are generally announced earlier in the year, the actual ceremony of awarding the prizes takes place annually on the anniversary of Nobel's death, December 10. A gold medal and a diploma accompany the money. The value of the prize varies; it was about $50,000 in 1915 and is now about $31,000.

Following are the Nobel Prize winners in physics, chemistry and medicine or physiology from the year 1901, when the prizes were first awarded, to the present time. We give the specific contributions for which prizes were granted.

Year	*Physics*	*Chemistry*	*Medicine or Physiology*
1901	*Wilhelm K. Roentgen* (Germany): discovery of Roentgen rays, or X rays.	*Jacobus H. van't Hoff* (Netherlands): discovery of laws of chemical dynamics and osmotic pressure.	*Emil A. von Behring* (Germany): research on use of serums against diphtheria.
1902	*Hendrik A. Lorentz* (Netherlands) and *Pieter Zeeman* (Netherlands): research on influence of magnetism upon radiation.	*Emil Fischer* (Germany): experiments in sugar and purin groups.	*Ronald Ross* (England): work on malaria.

Year	Physics	Chemistry	Medicine or Physiology
1903	*Antoine-Henri Becquerel* (France): research on spontaneous radioactivity. *Pierre Curie* (France) and *Marie Curie* (France; born in Poland): series of outstanding discoveries in the field of radiation.	*Svante A. Arrhenius* (Sweden): theory of electrolytic dissociation.	*Niels R. Finsen* (Denmark): treatment of lupus vulgaris with light-rays.
1904	*John Strutt* (Lord Rayleigh) (England): discovery of argon.	*Sir William Ramsay* (England): work on inert gases.	*Ivan P. Pavlov* (Russia): research on physiology of digestion.
1905	*Philipp Lenard* (Germany; born in Hungary): work on cathode rays.	*Adolph von Baeyer* (Germany): research on organic dyes and aromatic hydrocarbons.	*Robert Koch* (Germany): work on tuberculosis.
1906	*Joseph J. Thomson* (England): research on passage of electricity through gases.	*Henry Moissan* (France): isolation of fluorine; development of electric furnace.	*Camillo Golgi* (Italy) and *Santiago Ramón y Cajal* (Spain): research on structure of nervous system.
1907	*Albert A. Michelson* (U.S.): research on spectroscopy and metrology.	*Eduard Buchner* (Germany): discovery of cell-less fermentation; researches in biological chemistry.	*Charles L. A. Laveran* (France). research on role of protozoa in disease.
1908	*Gabriel Lippmann* (France): work on reproduction of colors by photography.	*Ernest Rutherford* (England): research on disintegration of elements and chemistry of radioactive substances.	*Paul Ehrlich* (Germany) and *Elie Metchnikoff* (Russia): work on immunity.
1909	*Guglielmo Marconi* (Italy) and *Karl Ferdinand Braun* (Germany): development of wireless.	*Wilhelm Ostwald* (Germany): research on catalysis, chemical equilibrium and rate of chemical reaction.	*Emil Theodor Kocher* (Switzerland): work on thyroid gland.
1910	*Johannes D. van der Waals* (Netherlands): theory of equation of state for gases and liquids.	*Otto Wallach* (Germany): work on alicyclic compounds.	*Albrecht Kossel* (Germany): research on chemistry of the cell.
1911	*Wilhelm Wien* (Germany): laws of radiation of heat.	*Marie Curie* (France; born in Poland): discovery of radium and polonium.	*Allvar Gullstrand* (Sweden): work on dioptics.
1912	*Gustaf Dalén* (Sweden): invention of automatic regulators for lighting lighthouses and light buoys.	*Victor Grignard* (France): discovery of Grignard reagent. *Paul Sabatier* (France): work on hydrogenation of organic compounds.	*Alexis Carrel* (U. S.; born in France): work on ligature and grafting of blood vessels and organs.
1913	*H. Kamerlingh-Onnes* (Netherlands): research paving way for production of liquid helium.	*Alfred Werner* (Switzerland): work on linking up atoms within the molecule.	*Charles Richet* (France): research on anaphylaxy.
1914	*Max von Laue* (Germany): discovery of diffraction of X rays passing through crystals.	*Theodore W. Richards* (U. S.): determining atomic weight of many elements.	*Robert Bárány* (Austria): research on physiology and pathology of vestibular system.

Year	Physics	Chemistry	Medicine or Physiology
1915	*W. H. Bragg* (England) and *W. L. Bragg* (England): analysis of crystal structure by use of X Rays.	*Richard Willstaetter* (Germany): work on nature of chlorophyll and other coloring matter of plants.	No award.
1916	No award.	No award.	No award.
1917	*Charles G. Barkla* (England): discovery of Roentgen radiation of the elements.	No award.	No award.
1918	*Max Planck* (Germany): work on quantum theory.	*Fritz Haber* (Germany): synthetic production of ammonia.	No award.
1919	*Johannes Stark* (Germany): decomposition of spectrum lines by electric fields; discovery of Doppler effect in canal rays.	No award.	*Jules Bordet* (Belgium): research on immunity.
1920	*Charles E. Guillaume* (Switzerland): research on nickel-steel alloys.	*Walther Nernst* (Germany): work on thermochemistry.	*Schack August Krogh* (Denmark): research on motor mechanism of capillaries.
1921	*Albert Einstein* (Germany): law of photoelectric effect.	*Frederick Soddy* (England): work on isotopes.	No award.
1922	*Niels Bohr* (Denmark): research on structure of atoms and radiations from atoms.	*Francis W. Aston* (England): discovery of isotopes in non-radioactive elements.	*Archibald V. Hill* (England): work on heat production in muscles. *Otto Meyerhof* (Germany): discovery of correlation between consumption of oxygen and production of lactic acid in the muscles.
1923	*Robert A. Millikan* (U. S.): research on photoelectric phenomena and charge on electron.	*Fritz Pregl* (Austria): micro-analysis of organic substances.	*Frederick G. Banting* (Canada) and *John J. R. McLeod* (Canada; born in Scotland): discovery of insulin.
1924	*Karl M. G. Siegbahn* (Sweden): work on X-ray spectroscopy.	No award.	*Willem Einthoven* (Netherlands): discovery of mechanism of electrocardiogram.
1925	*James Franck* (Germany) and *Gustav Hertz* (Germany): discovery of laws governing impact of electrons upon atoms.	*Richard Zsigmondy* (Germany; born in Austria): work on colloid solutions.	No award.
1926	*Jean-Baptiste Perrin* (France): work on discontinuous structure of matter; discovery of equilibrium of sedimentation.	*Theodor Svedberg* (Sweden): work on dispersion systems.	*Johannes Fibiger* (Denmark): researches on cancer.
1927	*Arthur H. Compton* (U. S.): discovery of Compton phenomenon. *Charles T. R. Wilson* (England): paths taken by electrically charged particles.	*Heinrich Wieland* (Germany): work on bile acids and similar substances.	*Julius Wagner-Jauregg* (Austria): use of malaria inoculation in treating dementia paralytica.

Year	*Physics*	*Chemistry*	*Medicine or Physiology*
1928	*Owen W Richardson* (England) work on thermionics discovery of Richardson Law	*Adolph Windaus* (Germany) work on constitution of sterols and their connection with vitamins	*Charles Nicolle* (France) work on typhus exanthematicus
1929	*Prince Louis Victor de Broglie* (France) discovery of wave character of electrons	*Arthur Harden* (England) and *Hans K A S von Euler Chelpin* (Sweden) work on fermentation or sugars	*Sir Frederick G Hopkins* (England) discovery of growth promoting vitamins of different kinds *Christiaan Eijkman* (Netherlands) discovery of antineuritic vitamins
1930	*Sir Chandrasekhara V Raman* (India) work on diffusion of light discovery of Raman effect	*Hans Fischer* (Germany) work on coloring matter of blood and leaves synthesis of hemin	*Karl Landsteiner* (U S born in Austria) discovery of human blood groups
1931	No award	*Friedrich Bergius* (Germany) and *Karl Bosch* (Germany) development of chemical high pressure methods	*Otto Warburg* (Germany) work on respiratory ferment
1932	*Werner Heisenberg* (Germany) development of quantum mechanics	*Irving Langmuir* (U S) work on surface chemistry	*Sir Charles S Sherrington* (England) and *Edgar D Adrian* (England) discovery of functions of neuron
1933	*Paul A M Dirac* (England) and *Erwin Schroedinger* (Austria) discovery of various new forms of the atomic theory	No award	*Thomas H Morgan* (U S) research on hereditary function of chromosomes
1934	No award	*Harold C Urey* (U S) discovery of heavy hydrogen	*George R Minot* (U S) *William P Murphy* (U S) and *George H Whipple* (U S) discovery of liver therapy in treatment of anemia
1935	*James Chadwick* (England) discovery of neutron	*Frederic and Irene Joliot Curie* (France) synthesis of new radioactive elements	*Hans Spemann* (Germany) discovery of organizer effect in embryonic development
1936	*Victor F Hess* (Austria) discovery of cosmic radiation *Carl D Anderson* (U S) discovery of positron	*Peter J W Debye* (Germany born in Netherlands) work on dipole moments and diffraction of X rays and electrons in gases	*Sir Henry H Dale* (England) and *Otto Loewi* (Austria) work on chemical transmission of nerve impulses
1937	*Clinton J Davisson* (U S) and *George P Thomson* (England) discovery of diffraction of electrons by crystals	*Walter N Haworth* (England) research on carbohydrates and vitamin C *Paul Karrer* (Switzerland) work on carotenoids, flavins and vitamins A and B	*Albert Szent-Gyorgyi von Nagyrapolt* (Hungary) research on biological combustion
1938	*Enrico Fermi* (Italy) identification of new radioactive elements nuclear reactions effected by slow neutrons	*Richard Kuhn* (Germany, declined the award) study of carotenoids, research on vitamins	*Corneille Heymans* (Belgium) research on importance of sinus and aorta mechanisms in regulation of respiration

FOUR NOBEL-PRIZE WINNERS

Wide World

Arthur H Compton (1892–) won the Nobel Prize in physics in 1927 for his discovery of the wave-length change found in scattered X rays

Wide World

Enrico Fermi (1901–) won the Nobel Prize in physics in 1938 for his work on radioactive elements and the effect of slow neutrons on nuclei

General Electric

Irving Langmuir (1881–) won the Nobel Prize in chemistry in 1932 for his many outstanding discoveries in the field of surface chemistry

Acme

Harold C Urey (1893–) won the Nobel Prize in chemistry in 1934 for his discovery of heavy hydrogen — deuterium, with an atomic weight of 2

Year	Physics	Chemistry	Medicine or Physiology
1939	*Ernest O. Lawrence* (U. S.): development of cyclotron.	*Adolph F. Butenandt* (Germany; declined the award): work on sexual hormones. *Leopold Ruzicka* (Switzerland): research on the polymetylenes.	*Gerhard Domagk* (Germany; declined the award): discovery of antibacterial effect of prontocilate.
1940	No award.	No award.	No award.
1941	No award.	No award.	No award.
1942	No award.	No award.	No award.
1943	*Otto Stern* (U. S.; born in Germany): detection of magnetic momentum of protons.	*Georg von Hevesy* (Hungary): work on use of isotopes as chemical indicators.	*Edward A. Doisy* (U. S.) and *Henrik Dam* (Denmark): discovery of the chemical nature of vitamin K.
1944	*Isidor Isaac Rabi* (U. S.): work on magnetic movements of atomic particles.	*Otto Hahn* (Germany): work on atomic fission.	*Joseph Erlanger* (U. S.) and *Herbert S. Gasser* (U. S.): research on functions of nerve threads.
1945	*Wolfgang Pauli* (Austria): work on atomic fission.	*Artturi Virtanen* (Finland): research in field of fodder conservation.	*Sir Alexander Fleming* (England), *Ernst Boris Chain* (Germany) ana *Sir Howard Walter Florey* (England): discovery of penicillin, derived from the mold *Penicillium notatum.*
1946	*Percy W. Bridgman* (U. S.): work on high-pressure physics.	*James B. Sumner* (U. S.): crystallizing of enzymes. *John H. Northrop* (U. S.) and *Wendell M. Stanley* (U. S.): preparation of enzymes and virus proteins in pure form.	*Herman J. Muller* (U. S.): research on hereditary effects of X rays on genes.
1947	*Sir Edward Appleton* (England): discovery of layer reflecting radio short waves in ionosphere.	*Sir Robert Robinson* (England): work on plant substances.	*Carl F. and Gerty T. Cori* (U.S.; born in Czechoslovakia): work on animal-starch metabolism. *Bernardo Houssay* (Argentina): hormone study of pituitary gland.
1948	*Patrick M. S. Blackett* (England): improvement on Wilson cloud chambers; series of outstanding discoveries in cosmic radiation.	*Arne Tiselius* (Sweden): biochemical discoveries; isolation of mouse-paralysis virus.	*Paul Mueller* (Switzerland): discovery of insecticidal properties of DDT.
1949	*Hideki Yukawa* (Japan): for mathematically predicting existence of meson.	*William F. Giauque* (U. S.; born in Canada): research in field of thermodynamics.	*Walter R. Hess* (Switzerland): work on brains of dogs and cats; discovery of how parts of brain control different parts of body. *Antonio Caetano de Abreu Freire Egas Moniz* (Portugal): development of brain operations for treatment of mental illness.

Year	*Physics*	*Chemistry*	*Medicine or Physiology*
1950	*Cecil Frank Powell* (England): development of simple photographic method for studying atomic nucleus; work on mesons.	*Otto Diels* (Germany) and *Kurt Adler* (Germany): developing Dien synthesis by which odors and complicated compounds are made artificially.	*Philip S. Hench* (U. S.), *Edward C. Kendall* (U. S.) and *Tadeus Reichstein* (Switzerland; born in Poland): discoveries regarding hormones of adrenal cortex, their structure and their biological effect.
1951	*Sir John Cockcroft* (England) and *E. T. S. Walton* (Ireland): experiments in splitting atomic nuclei with artificially propelled "bullets."	*Glenn T. Seaborg* (U. S.) and *Edward M. McMillan* (U. S.): discovery of plutonium.	*Max Theiler* (South Africa): discovering effective vaccines protecting human beings against yellow fever.
1952	*Felix Bloch* (U. S.) and *Edward M. Purcell* (U. S.): development of new method of measuring magnetic fields in atomic nuclei.	*Archer Martin* (England) and *Richard Synge* (Scotland): development of paper partition chromatography.	*Selman A. Waksman* (U. S.): discovery of streptomycin, first effective antibiotic against tuberculosis.

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ALPHABETICAL INDEX

THE heavy face number against a reference is that of the volume in which it appears; the light face number gives the page. Where two of the latter are separated by a dash it shows that the reference extends from one to the other. For example:

Telephone.
Picture Transmission by Wire, *with illus.*, **7**, 2928-30

indicates that information on the transmission of pictures by telephone will be found in volume **7** on pages 2928 to 2930 inclusive, together with illustrations. Cross references at the end of indexed subjects avoid duplication and should be consulted. The alphabetization is that preferred by the American Library Association—that is by first word and not "straight through." For example: **Child Labor** (2 words) precedes **Childbirth; Chimney swift** precedes **Chimneys.** Hyphenated words are considered two separate words.

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